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EDITOR OF DART SIMULATIONS

User's manual

Reference:	DART User Manual-V1.doc
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This document presents the principal functions of the editor of DART simulations.

I Environment for running the simulation editor

I.1 Definition of a "DART simulation"

The whole set of all DART input parameters is called "DART simulation". It contains:

- the description of a scene:
  - scene size, digital elevation model, etc.
  - geometrical elements, natural or urban (walls, roads, trees, lake, rivers, houses, buildings...), that compose it,
  - optical and thermal characteristics of the elements,
  - description of the atmosphere
- a set of parameters of calculation:
  - method of calculation (DART/Monte Carlo)
  - spectral bands,...
- a list of the products of exit:
  - total radiative budget,
  - images,...

The parameters of a simulation are stored on hard disk in structured XML files:

- Atmosphere.xml
- Coeff_diff.xml
- Dart.xml
- Directions.xml
- Maket.xml
- Phase.xml
- Urban.xml
- Vegetation.xml

The editor of Simulations ensures the coherence of the data of the files.
The construction of the interface being fully dynamic and being controlled by the structure of the data files, the user is ensured of coherence of the visualized/saved data.

I.2 DART tree arborescence

The editor of simulations respects the tree structure described by the environment of execution of DART system.

I.3 Context of use

The editor is a graphic application that gives a global view of all parameters defining a DART simulation. It allows the edition of all parameters defining a DART simulation. It is used for creating and modifying a simulation.

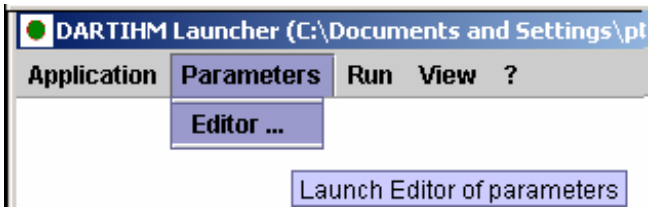
I.4 Run of the editor

The editor of Simulations is run through the DART launcher.

A simulation is a directory which contains the 3 directories:

- Log: contains files tracing the standard exits and errors of each executable run with the launcher.
- Input: it contains no file at the right beginning of a new simulation. After a safeguard, it contains the xml files.
- Output: contains the output files of the calculator

Note: the title of the window of the launcher allows one to verify that the current simulation is in directory $DART_LOCAL/simulations.



From the menu *Parameters*, click on the *Editor…* Then, the simulation editor loads current simulation or default simulation and its window appears.

II Description of the editor

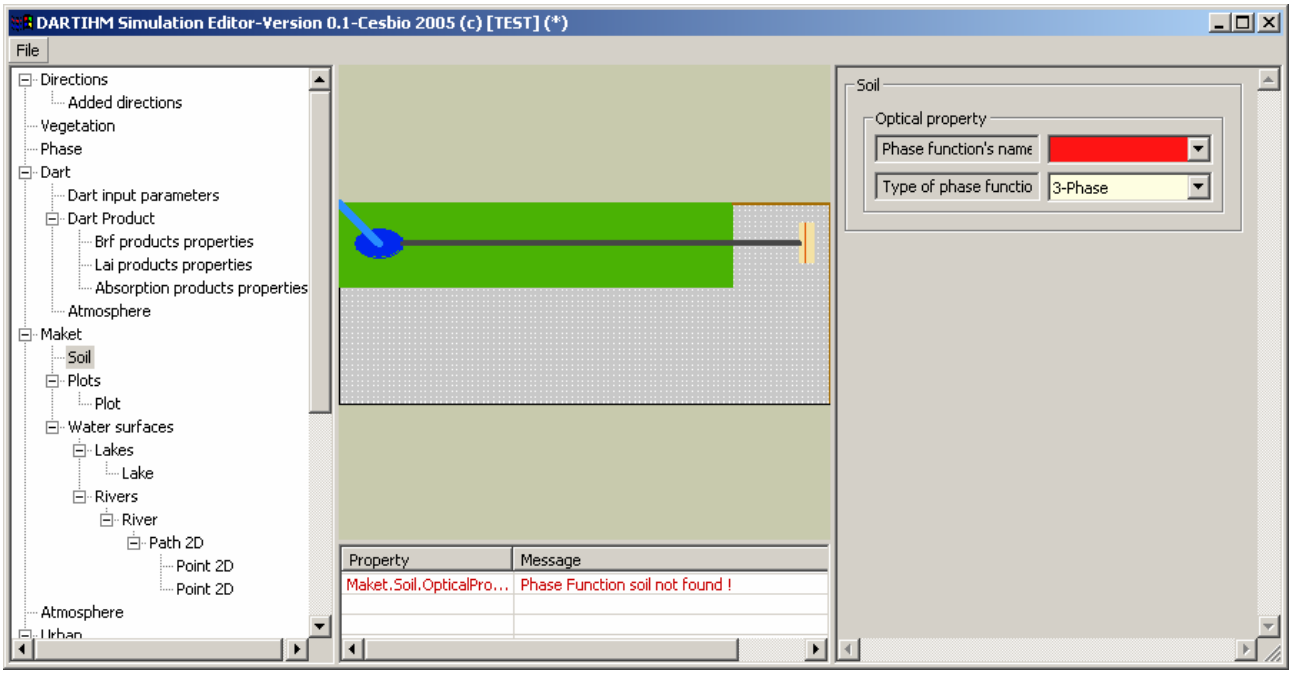


Figure II.1: *Graphic User interface (GUI)*

The interface of edition is divided into 5 zones:

- a menu of access to the general functions (initialization of a new simulation, opening of a simulation, safeguards simulation in progress, to leave the application),
- a hierarchical tree of navigation of the structure of the data offering the functions of addition, suppression of nodes of data,
- a chart window of visualization of the scene,
- a zone of visualization and input of the parameters,
- a table of the errors associated to the validation of the current simulation.

II.1 The main menu

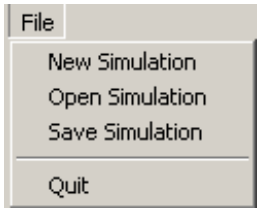


Figure II.2: *Main menu*

New Simulation	Creates a new simulation
Open Simulation	Opens an existing simulation
Save Simulation	Saves the current simulation
Quit	Leaves the editor

II.2 The navigation tree

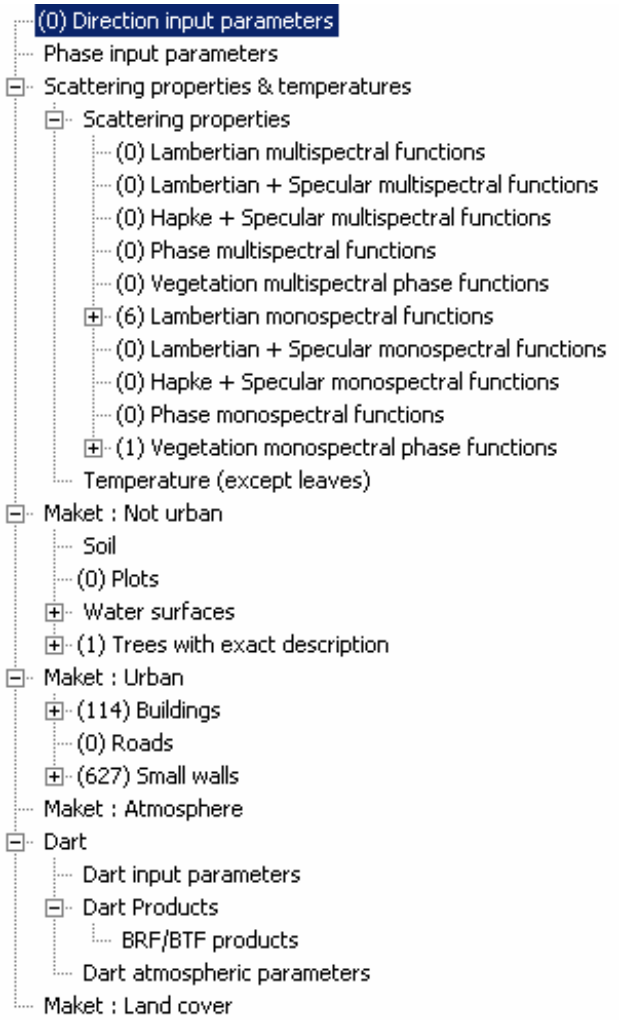


Figure II.3: *Tree of navigation: display in* hierarchical form the nodes of data.

The eight root nodes correspond to the 8 backup files of the data of a simulation (corresponding to the 8 independent modules of the calculator):

Name of the node	Name of the file of parameters
Directions	directions.xml
Vegetation	vegetation.xml
Phase	phase.xml
Dart	dart.xml
Maket	maket.xml
Atmosphere	atmosphere.xml
Urban	urban.xml
Coeff_diff	coeff_diff.xml

The tree structure is dynamically built starting from the data present in the parameter files. The contextual menu accessible by right click allows the addition or the removal of simulation element when that is allowed.

To indicate the nodes allowing the addition of element, a figure corresponding to the number of elements present in the node is displayed between brackets.

Navigation and selection of the current node of data

The tree of navigation makes it possible to select the current node, whose parameters are posted then in the window of edition of the parameters.

Edition

A dynamic contextual menu (right button click) makes it possible to add or remove nodes of data in simulation.

On a node containing a variable list of sub-nodes (example: "Building" can have a variable number of nodes "House"), the function "Add" of the contextual menu is un-grayed and proposes the list of nodes that can be inserted (here, only nodes of the type "House" can be added to a node "Building").

Figure II.4: *Contextual menu of the tree*

On an optional node (belonging to a variable list of nodes of which one did not reach the minimal number of occurrence yet) the function "Remove" is un-grayed, allowing to remove the selected node of the simulation.

II.3 The graphic display window of the scene

The graphic display window visualizes the elements constituting the scene:

- lakes
- rivers
- houses
- walls
- roads
- various vegetation plots
- plots containing trees

The element in the course of edition is marked of a red edging.

Note: trees do not appear in the 2D display window of the present GUI version. They appear only in the 3D-display. This problem is being solved for the next version.

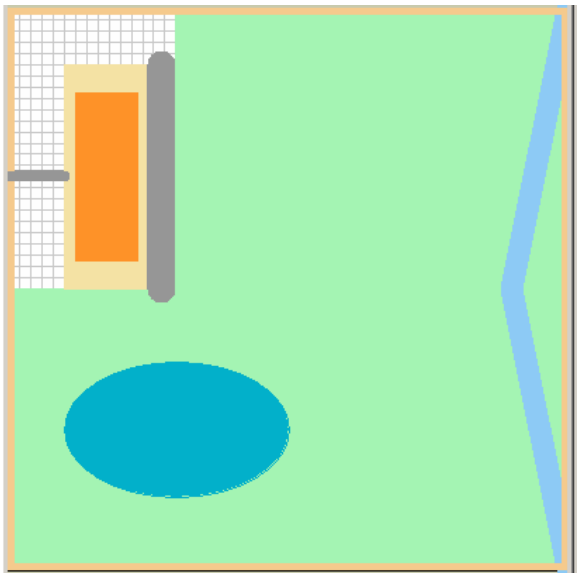


Figure II.5: *Graphic display window of the scene*

Selection of a scene element:

The display window makes it possible to directly select the nodes of data associated with the scene graphic elements, with a "left click" on the graphic element. That causes to select in the associated tree item, to open and post its parameters in the zone of edition.

II.4 The window of edition of the properties

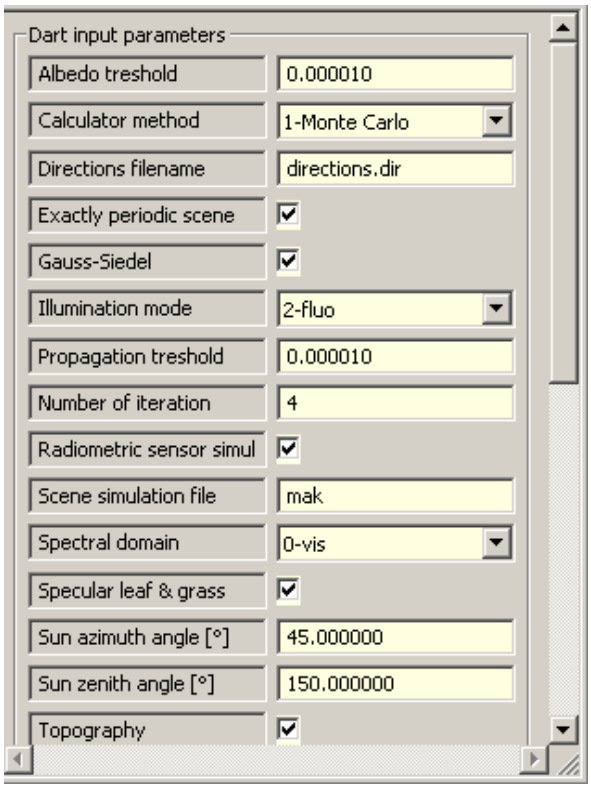


Figure II.6: *Graphic display window of the scene*

The contents of the window adapt dynamically, according to the node of data selected (starting from the tree or of the display window).

The window shows the parameters of the current node and thus makes it possible to visualize and edit its parameters.

Certain data influence directly the structure of the file (boxes to notch, boxes of selection). These modifications are dynamically reflected on the level of the GUI (appearance or disappearance of fields of input parameters)

The passage and holding of the cursor of the mouse over an input field or on its label reveals (if it is available) a description of the pointed field.

When an input is considered as no valid, (formatting not respected, value out of range, non existing phase function,...), a red bottom appears in the corresponding input fields.

II.5 The table of the errors of validation

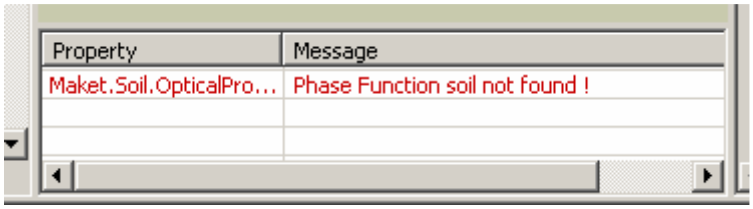


Figure II.7: *Table of the errors of validation*

This window appears only if a validation error is detected in the current document. Then, the window shows in the shape of a table all validation errors detected in the document:

- The column "Property" indicates the access path to the invalid property (parameter).
- The column "Message" indicates the associated error message

The causes of invalidity of a field are as follows:

- Badly formatted field (presence of unexpected character),
- Value seized out of the interval of definition,
- Non existing phase function,
- Input file absent of the local filing system.

A click on a line of the table allows one to reach the edition of the erroneous parameter.

IIIGRAPHIC INTERFACE

III.1 Main window

- Menu *"Application"*: Used to create a new simulation or to load a previous simulation.
- Menu *"Parameters"*: Opens an editor used to specify all parameters for all DART modules. A priori parameters are usually proposed in order to ease the operator.
- Menu *"Run"*: Used to run the executable modules DIRECTIONS, PHASE, MAKET and RT_DART.
- Menu *"View"*: Used to view the landscape computer simulation, images and some results.

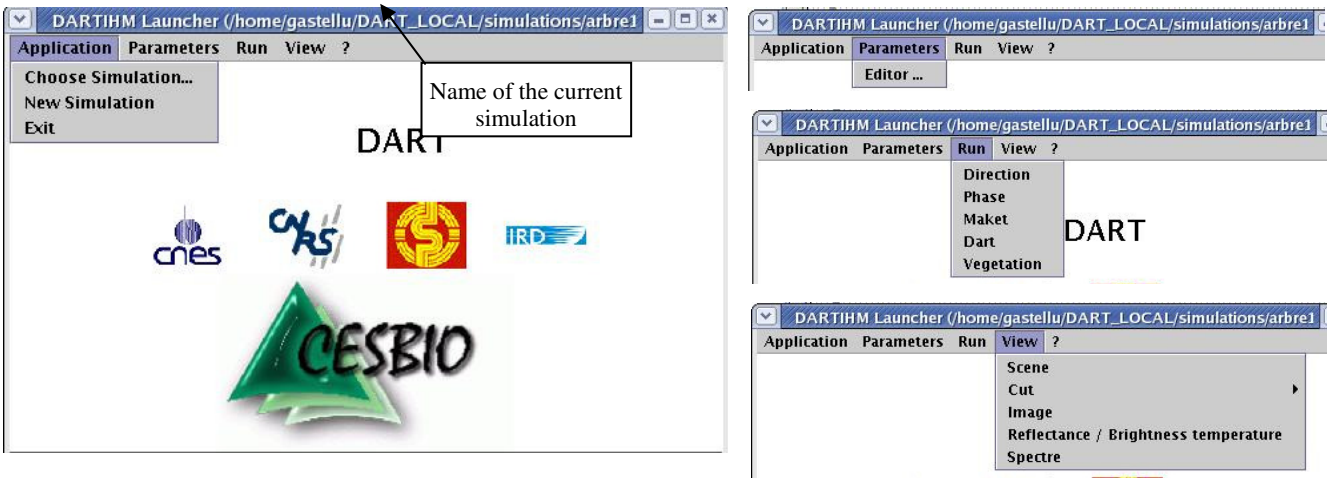


Figure III.1 : Welcome menu of DARTI.

a) Creation of a new simulation or selection of a previous one. b) Parameter editor. c) DART executables. d) Display of the scene and of a few DART results.

III.2 Direction

This menu is used to create the N_{dir} propagation directions. The 4π space is homogeneously sampled. In addition, the solar plane and the perpendicular plane can be oversampled. Similarly, the propagation space around the hot spot can be oversampled. Values (θ_i, φ_i, $\Delta\Omega_i$) are stored in file *directions.dir*.

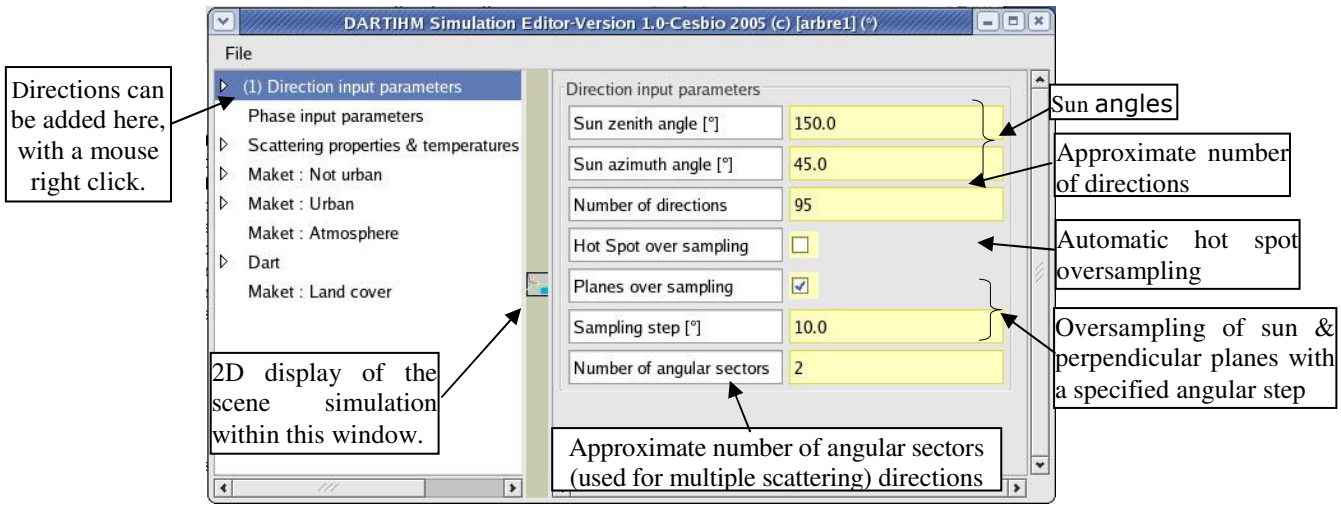

DARTIHM Simulation Editor-Version 1.0-Cesbio 2005 (c) [arbre1] (*)
File
(1) Direction input parameters
Phase input parameters
Scattering properties & temperatures
Maket : Not urban
Maket : Urban
Maket : Atmosphere
Dart
Maket : Land cover
Direction input parameters
Sun zenith angle [°] 150.0
Sun azimuth angle [°] 45.0
Number of directions 95
Hot Spot over sampling
Planes over sampling
Sampling step [°] 10.0
Number of angular sectors 2
Directions can be added here, with a mouse right click.
Sun angles
Approximate number of directions
Automatic hot spot oversampling
Oversampling of sun & perpendicular planes with a specified angular step
2D display of the scene simulation within this window.
Approximate number of angular sectors (used for multiple scattering) directions

Figure III.2 : *Parameters for the "Direction" module*.

III.3 Phase input parameters

This menu is used to specify some general parameters:

- Radiative transfer method: flux tracking or Monte Carlo (only for mode R without "RT within the air of BA".)
- Name of the file that contains the directions (θ, ϕ, $\Delta\Omega$, sector number)
- Sun direction
- Spectral mode: monospectral or multispectral
- Account or not of vegetation specular reflexion

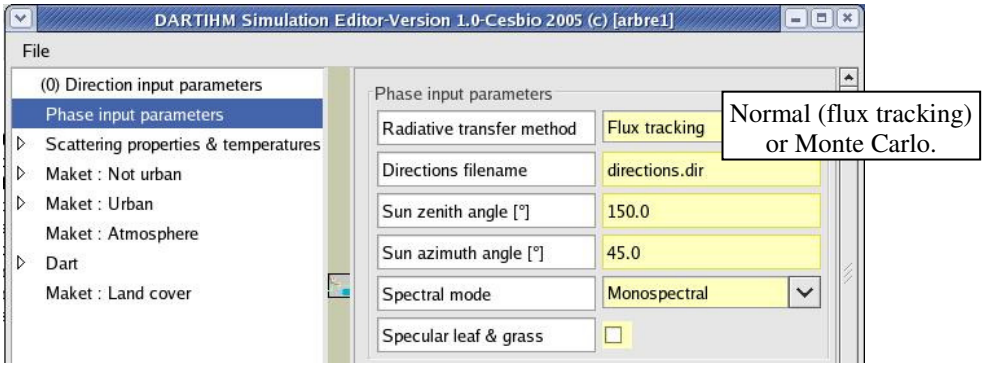


Figure III.3: *"Phase input parameters" menu.*

III.4 Scattering properties and temperatures

This menu specifies the extreme temperatures of scene elements other than leaves, and also the optical monospectral and multispectral parameters of:

- *Opaque surfaces*: Lambertian, Hapke and Phase functions. With Lambertian and Hapke functions, scattering is computed on the fly with the specified parameters. On the other hand, Phase functions represent pre-computed scattering transfer matrices M associated to Lambertian and Hapke functions. This is intended to speed up the calculation of scattering by horizontal opaque surfaces. Actually, these M scattering matrices could be replaced by any scattering matrices computed with any model.
- *Vegetation*: Vegetation phase functions.

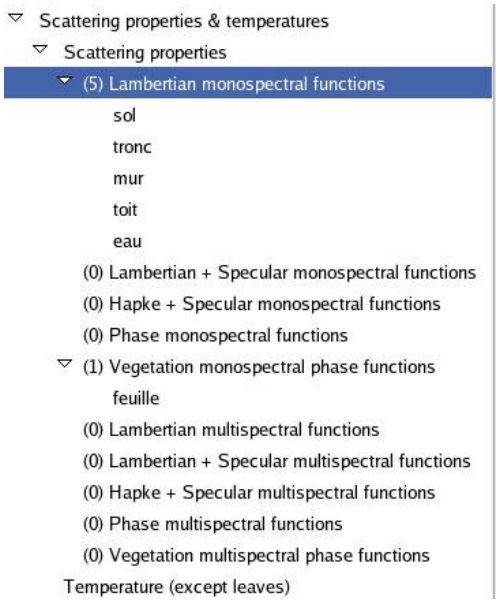


Figure III.4 :

"Scattering & Temperatures" menu.

Only monospectral functions are defined: 5 lambertian + 1 vegetation. As usual, new functions are added with a right click on the the selected function.

Optical parameters are directly input with monospectral functions, whereas they are derived from spectral databases with multispectral functions.

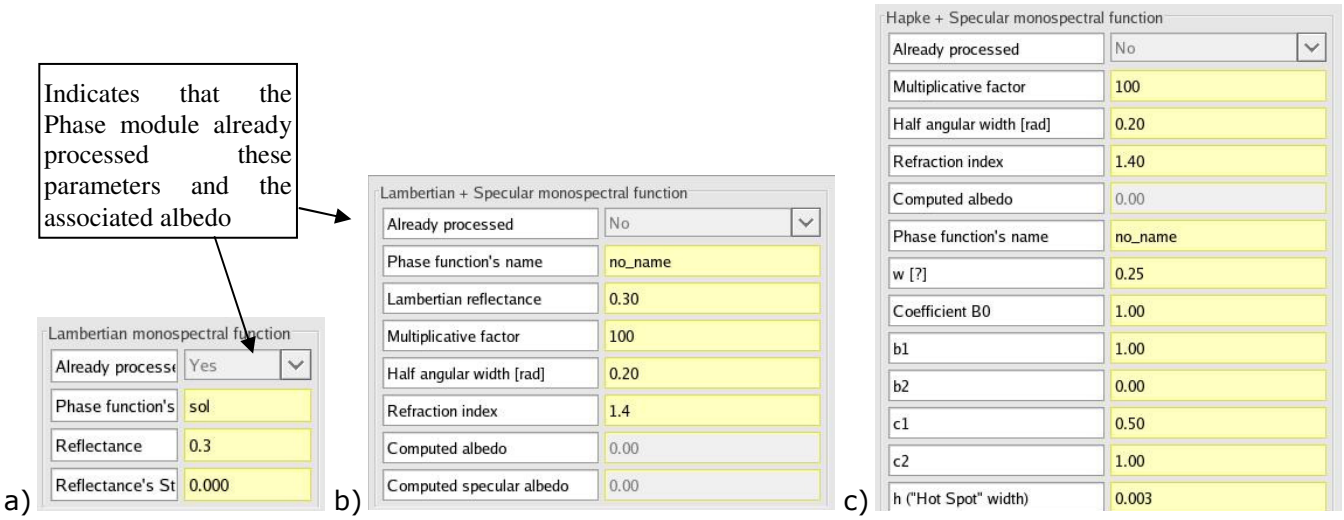


Figure III.5 : Parameters of scattering monospectral functions for opaque surfaces.
a) Lambertian. b) Lambertian + specular. c) Hapke + specular.

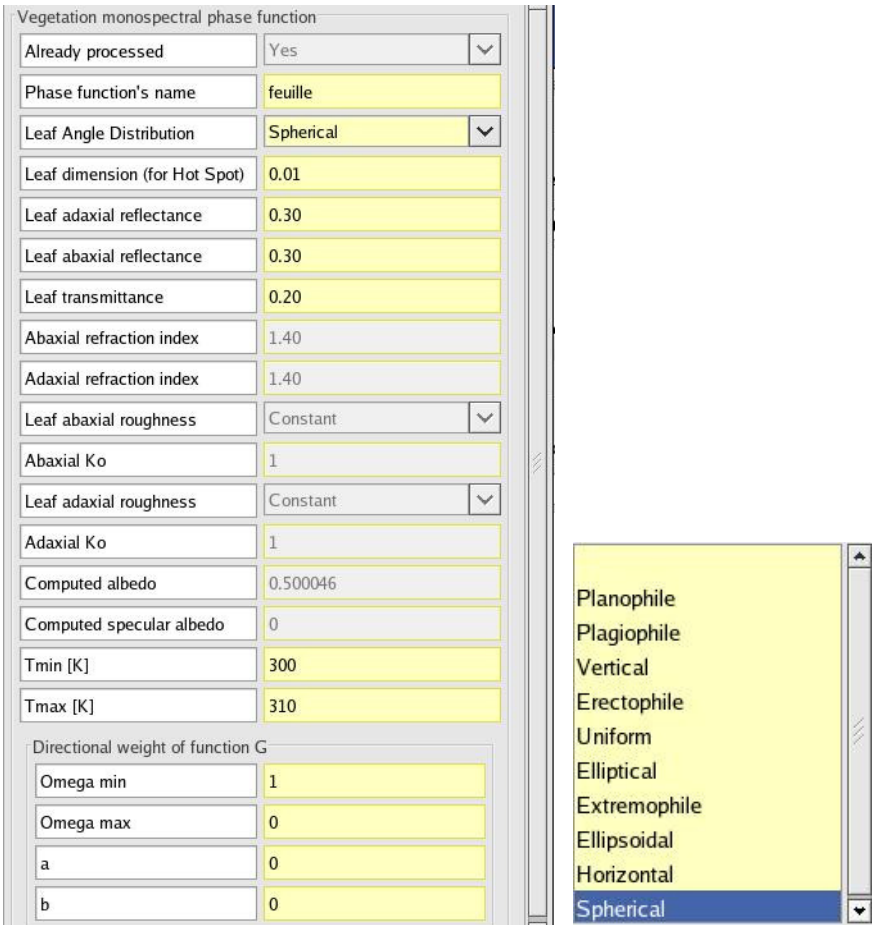


Figure III.6: Parameters of "Vegetation monospectral phase function" and the 10 pre-defined LADs.

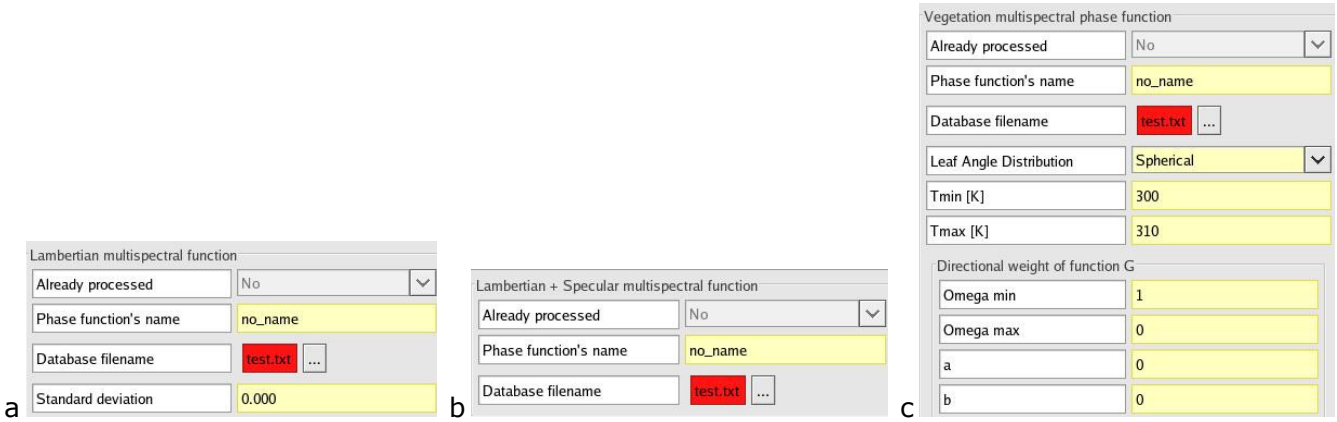


Figure III.7 : Parameters of scattering multispectral functions for opaque surfaces.
a) Lambertian. b) Lambertian + specular. c) Hapke + specular.

III.5 Maket

III.5.1 Maket: not urban

It specifies general parameters:

- cell and scene dimensions,
- presence of a bounding wall that bounds partly or totally the DART scene.
- presence or not of trees. If trees are present, the user must specify the type of tree distribution. Indeed, trees can be randomly located, exactly located with mean dimensions and exactly located with exact dimensions. The exact characteristics (location and possibly dimensions) of each tree are stored in a text file. If trees are present, and only in this case, the user can extract from the specified scene the actual DART scene. In that case, the crowns of trees located right outside the DART scene can appear in the DART scene whereas t trunks of these trees do not appear.
- type of DART scene: exactly periodic or not.

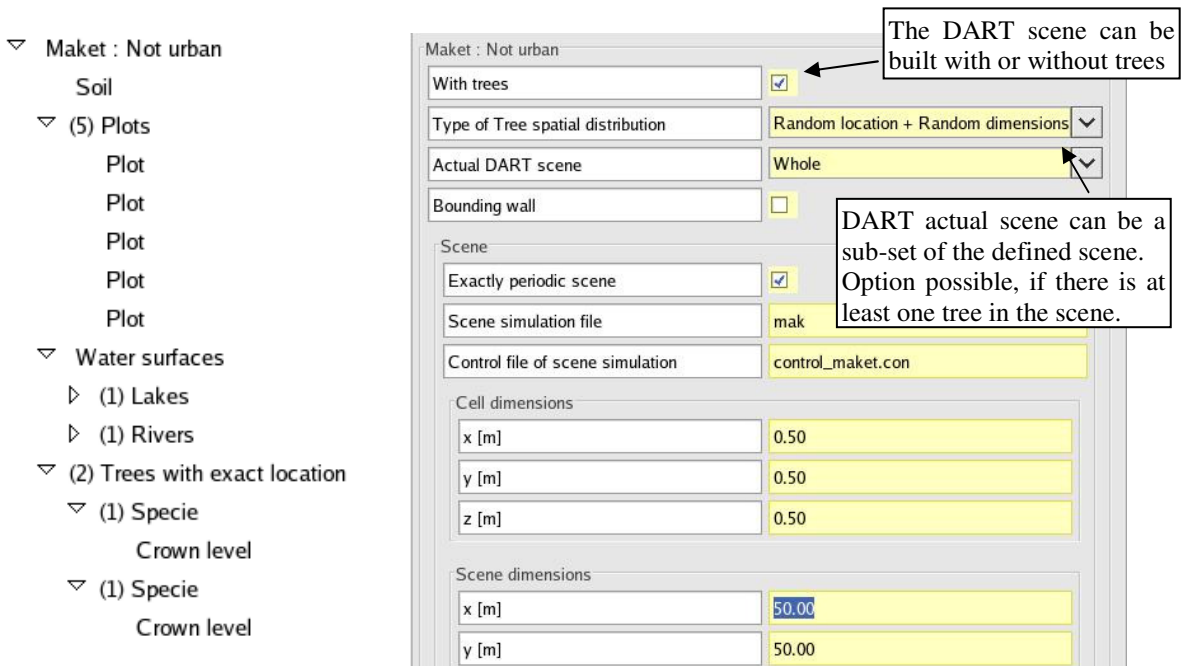


Figure III.8 : Parameters of "Maket: not urban" menu.

The user must define all elements that are present in the scene. The only element that is always present is "soil". For each element (soil, plot, water surface, tree) that is present in the scene, the user must specify the optical properties, and also the geometric characteristics. Optical properties are defined by the type of phase function and the name of one of the functions of this type that were already defined with the help of the parameters entered in the "Scattering properties and Temperature" module.

a) ***Soil***

Optical properties, presence or not of topography, and in that case, the DEM file name.

b) ***Plot***

Its projection over an horizontal plane is a quadrilateral (4 points). It can be (1) a soil surface that is simply superimposed over the soil surface of the DART scene, (2) a vegetation parallelepiped with a bottom interface that is the soil surface of the DART scene, and (3) a vegetation parallelepiped with a soil surface that is superimposed over the soil surface of the DART scene.

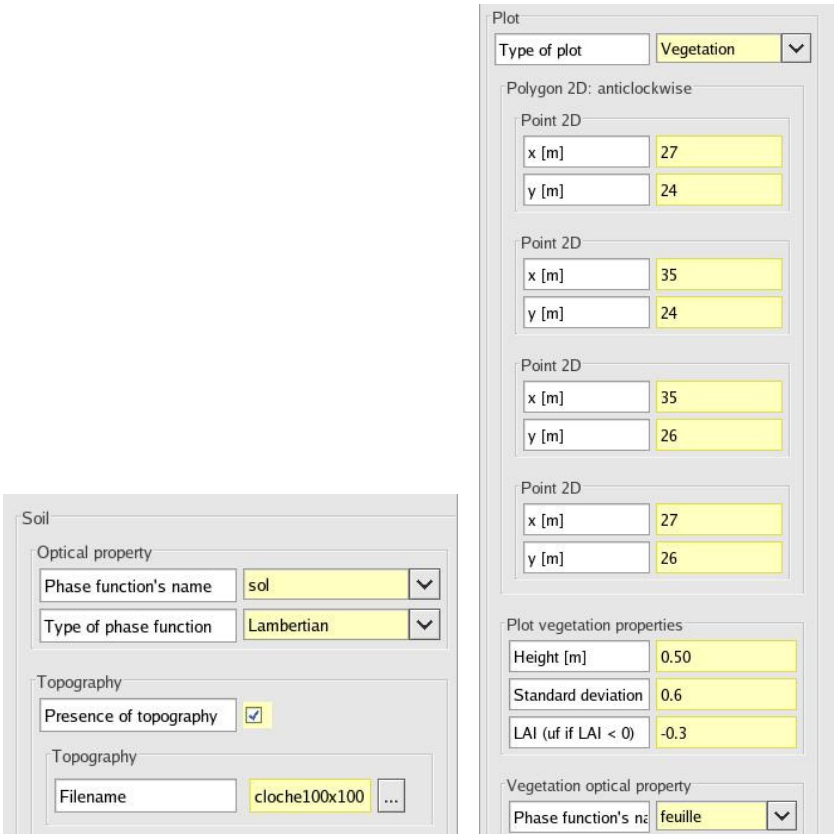


Figure III.9 : Parameters of (a) the soil surface of the scene and (b) of a "vegetation" plot.

c) ***Water surface***

Lakes and rivers are the 2 types of water surfaces. They can be priority on vegetation plots. Each is defined by an opaque scattering function and its projection on a horizontal plane:

- lake: ellipse defined by its center and its two axes along the x and y axes.
- river: segments between successive points (x,y), and with a specified width.

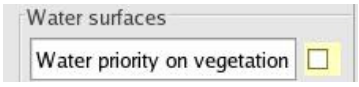


Figure III.10 : *Selection of water priority on vegetation.*

Figure III.11: Parameters of a river.

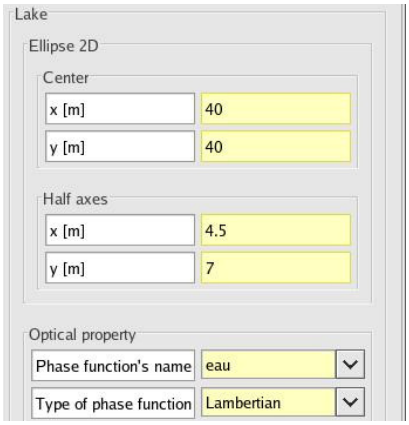


Figure III.12 :

Parameters of a lake.

d) ***Trees***

Their number is given. There can be several tree species (specific leaf/ trunk optical properties).

1. *Random tree location*. For each specie, trees are within circles around the nodes of a grid spread over the whole scene (grid option), a quadrilateral (zone option) or an ellipse (FctDistribution option). Actually, the tree presence within a circle depends on the probability presence, and it is more or less homogeneous within this circle depending on the position standard deviation. The grid is defined by the inter trees distances along the Ox and Oy axes. Trees are characterized by trunk optical properties, a "crown shape" and a specific mean geometry: mean and standard deviation of trunk diameter, crown dimensions, and also trunk height below and within crown.

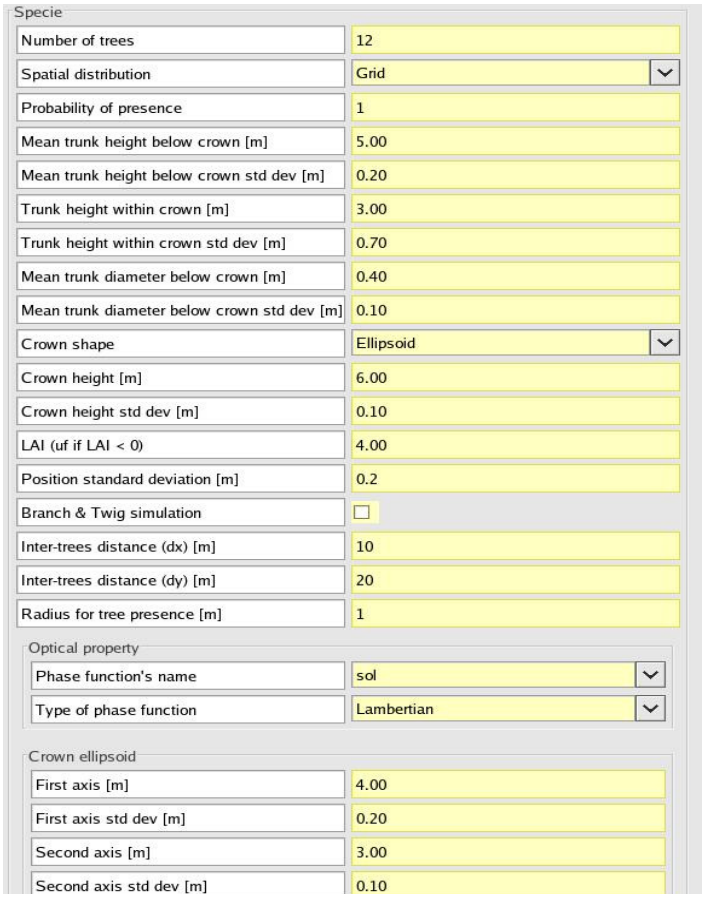


Figure III.13 :

Tree random location.

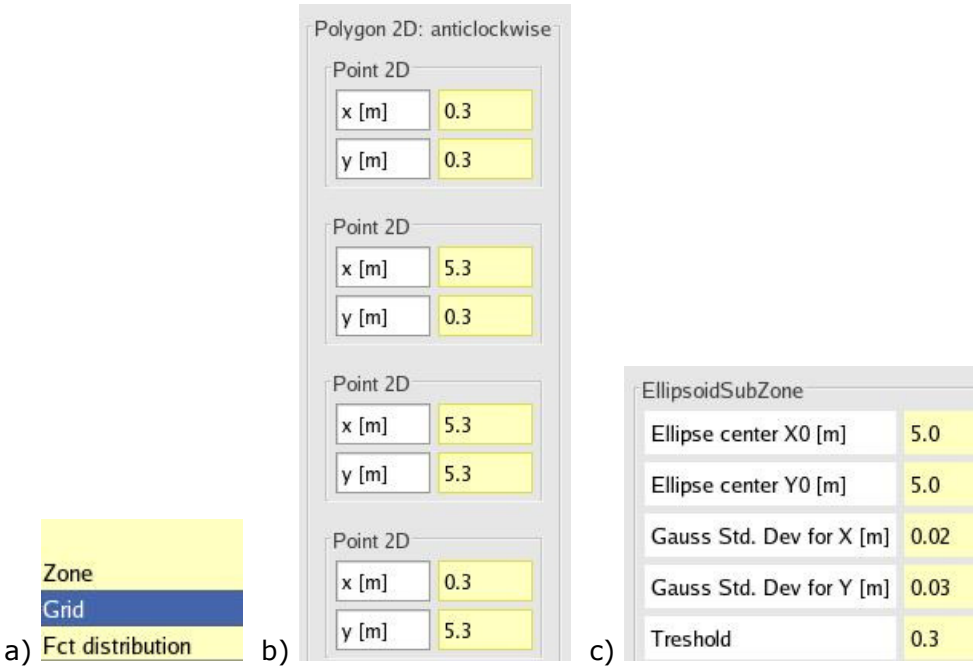


Figure III.14 : The 3 types of areas where trees are located in the case "Random location".

Trees can contain twigs and branches. For that, the user validates the option "Branch & twig simulation". The information about twigs and branches is stored in a text file. The quantity of twigs is specified with the TAI (Twig Area Index). The user can also specify the possibility that there is "branch + twig" mixing, which means that an individual cell can contain both branches and twigs. Branches and twigs are characterized by specific optical properties.

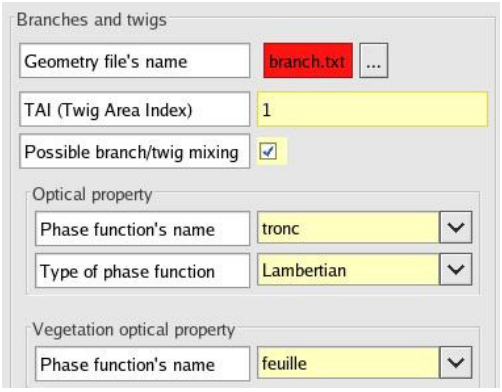


Figure III.15 :

"Branches + Twigs" option

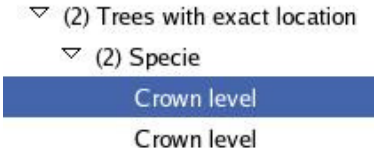


Figure III.16 :

Specification of the number of crown levels.

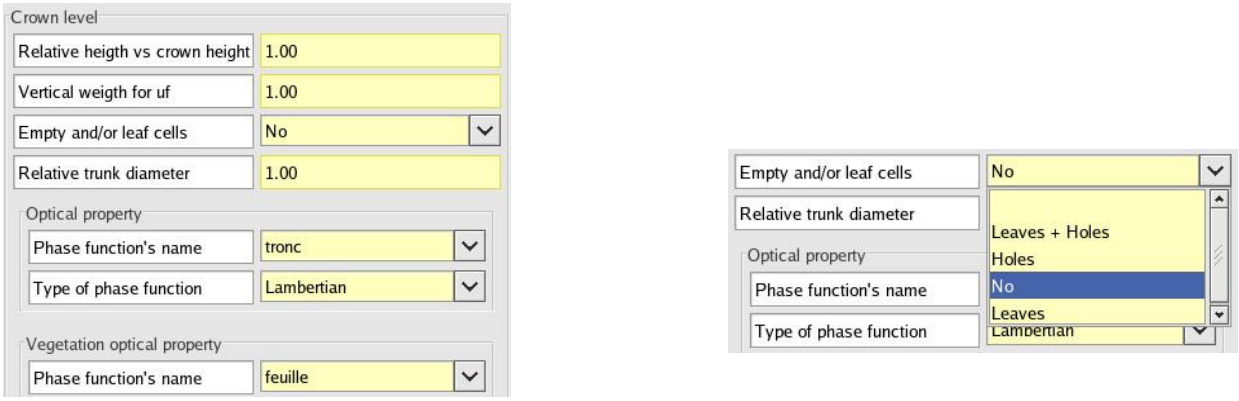


Figure III.17 : Description of a crown level. Without horizontal profile of "holes" and leaves.

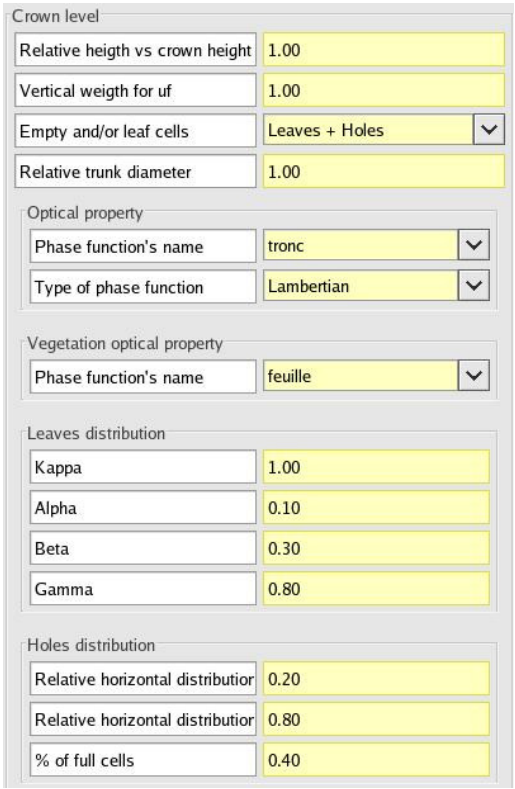


Figure III.18 :

Description of a crown level.

Horizontal profiles of "holes" and leaves.

2. *Exact location + mean characteristics*: a text file gives for each tree its location and the index of its species (i.e., leaf and trunk optical properties and also a mean geometry). If the text file does not exist, the user can create it with a "grid distribution" for trees, similarly to option 1).

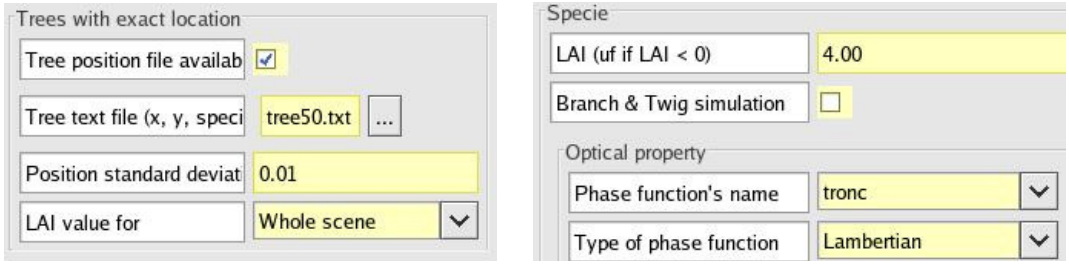


Figure III.19 : Exact tree location + Random parameters" option.

3. *Exact location + exact characteristics*: a text file gives for each tree its location, geometry and its species index. Here, a species refers to "leaf + trunk" optical properties.

III.5.2 Maket: urban

a) ***Building***

A building is a set of houses the walls and roofs of which can have the same optical properties.

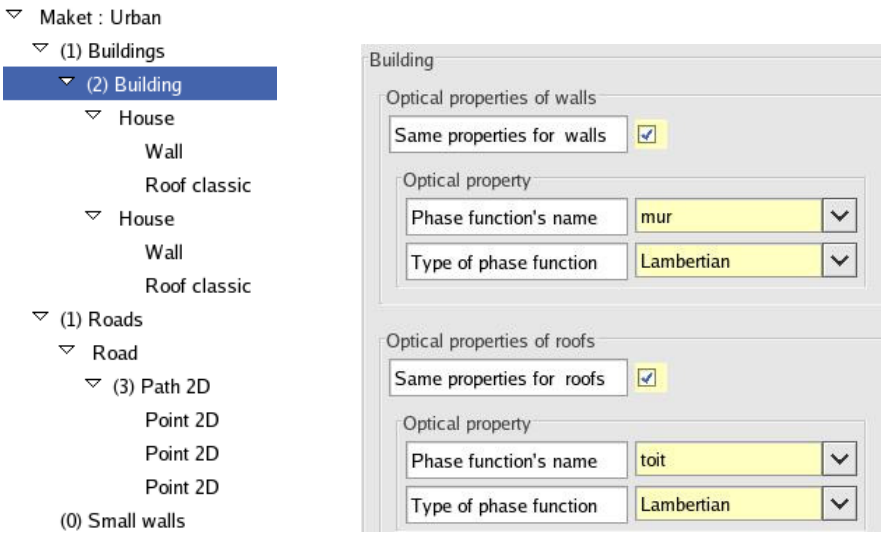


Figure III.20 : "Building" menu.

b) ***Houses***

A house is made of 4 walls and a roof. Their optical properties can be defined in the "building" menu.

Walls: they are defined by the 4 upper corners, given in the anticlockwise. Optical properties can be specified for each wall.

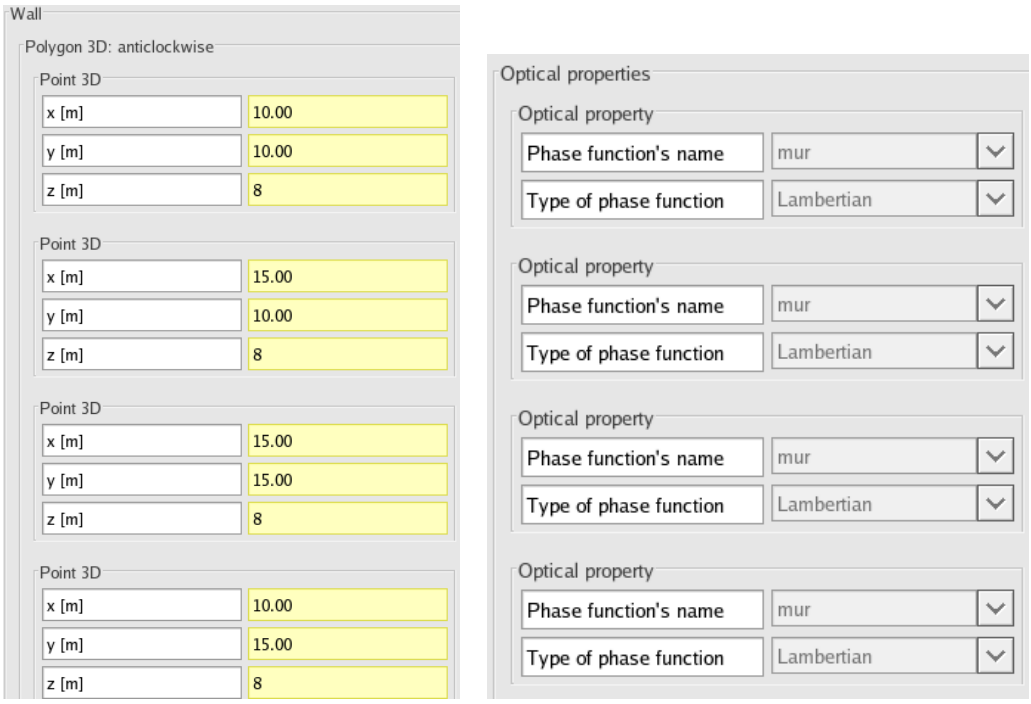


Figure III.21 : "Building" menu.

Roofs: we can have "no roof", "plate roof", "classic roof" and "complex roof".

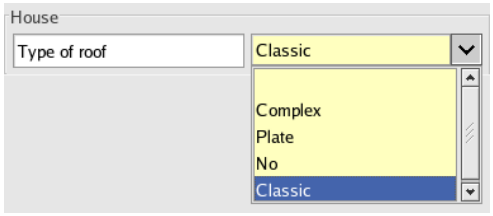


Figure III.22 : Menu for selecting the type of roof.

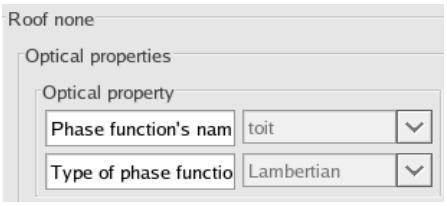


Figure III.23 : "No roof" menu.

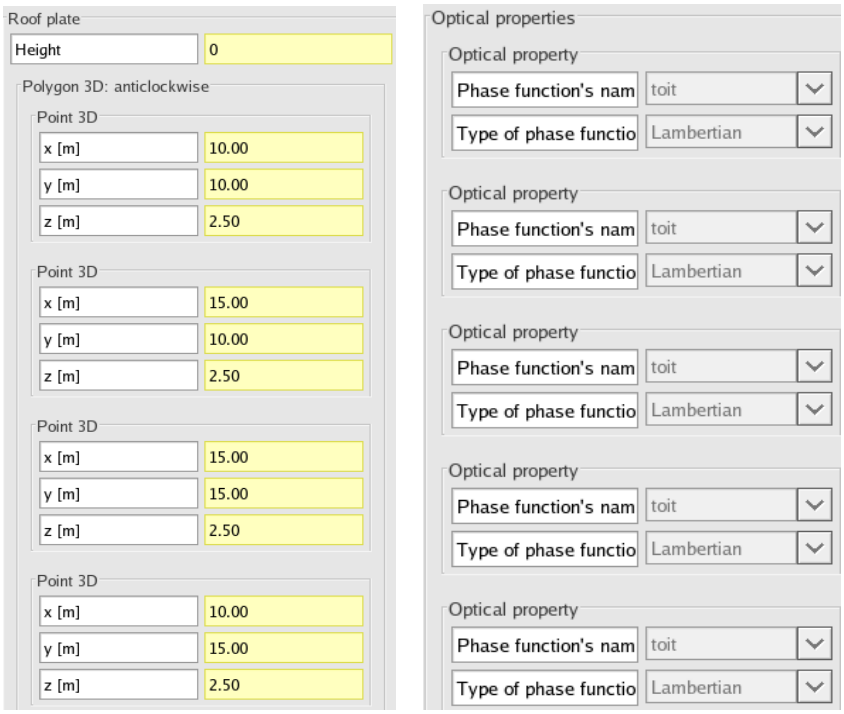


Figure III.24 : "Plate roof" menu.

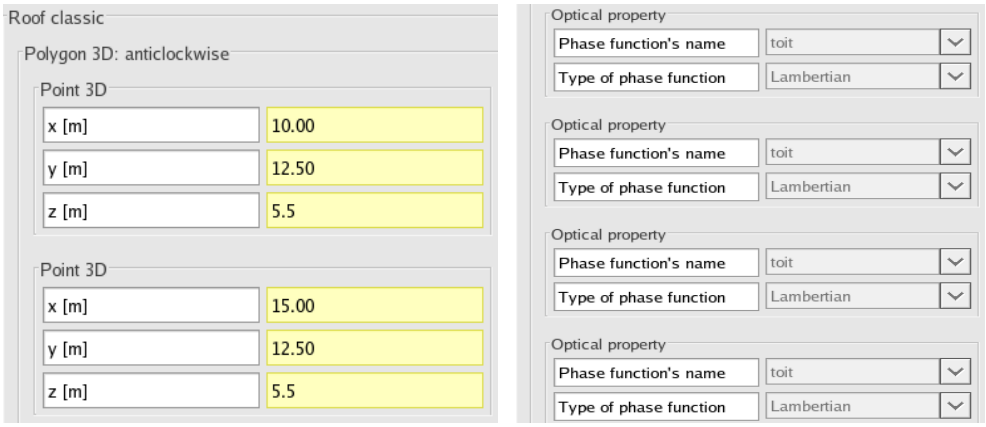


Figure III.25 : "Classic roof" menu.

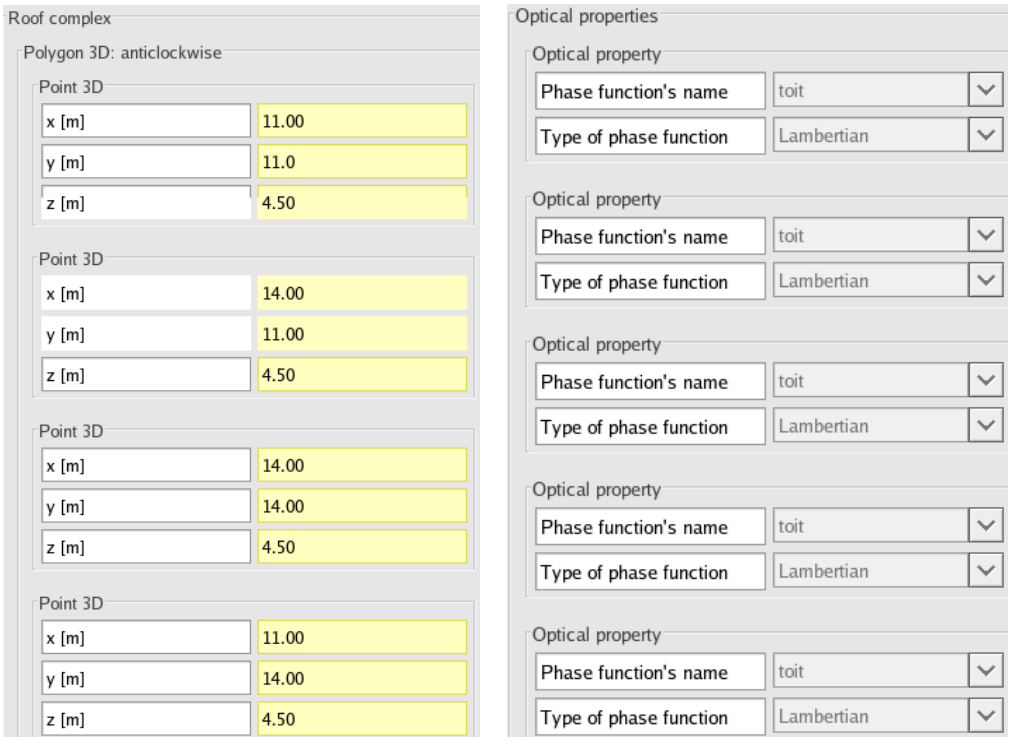


Figure III.26 : "Complex roof" menu.

c) **Roads**

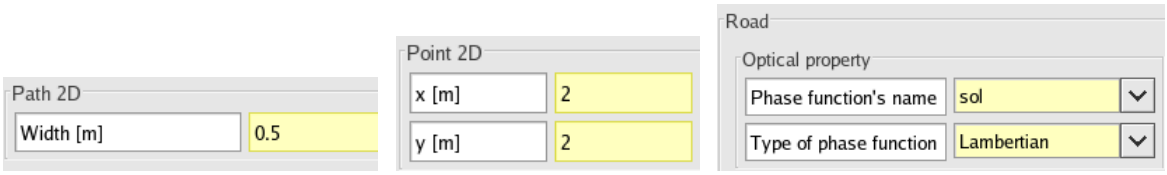


Figure III.27 : "Road" menu.

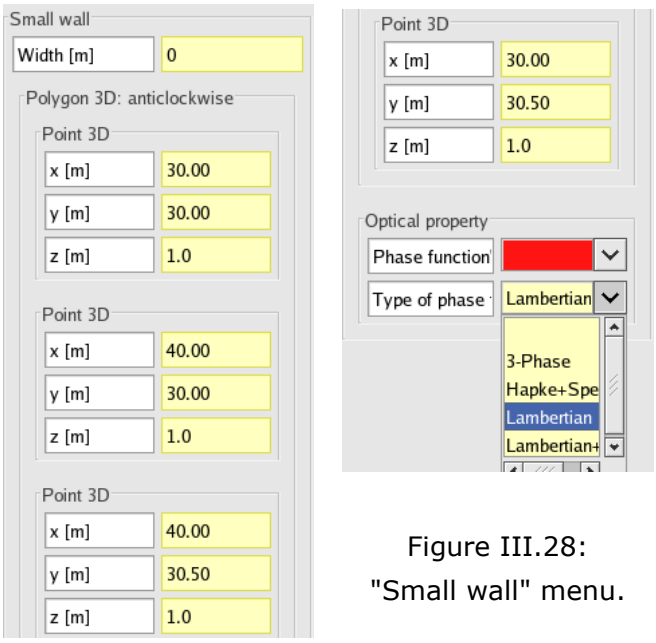


Figure III.28:
"Small wall" menu.

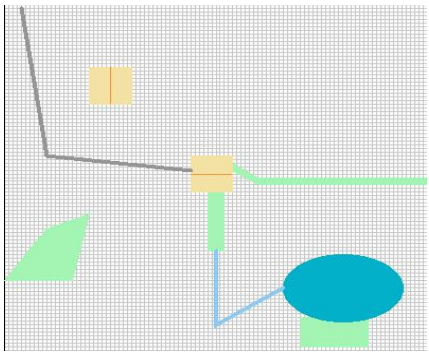


Figure III.29:

Graphic User Interface with the 2-D "nadir" display of the DART scene.

*Trees are not displayed. They appear in the 3-D viewer (*Figure III.44:*).*

III.5.3 Maket: atmosphere

The "Maket: Atmosphere" menu describes the atmosphere, if there is an atmosphere (*i.e.*, atmospheric radiative transfer). The "DART input parameters" menu specifies:

1.) *no atmosphere* : "none" (same "isotropic atmosphere" + SKYL = 0)

2.) *atmosphere without atmospheric radiative transfer*:

* "isotropic atmosphere" with a specified SKYL,

* "anisotropic atmosphere" with a text file that stores a sky irradiance angle distribution.

3.) *atmosphere with atmospheric radiative transfer*:

* "without atmosphere data base" (input parameters in the "Maket: Atmosphere" menu),

* "with atmosphere data base" (input parameters in the "Maket: Atmosphere" menu).

In both cases, the user specifies the sensor height and the sun constant.

• ***Atmosphere without data base***

- Input parameters for aerosols: height scale factor, optical depth, albedo and coefficients (g_1, g_2, a) of the Greenstein function (phase function).
- Input parameters for gases: height scale factor, optical depth associated to scattering, and transmittance associated to absorption.

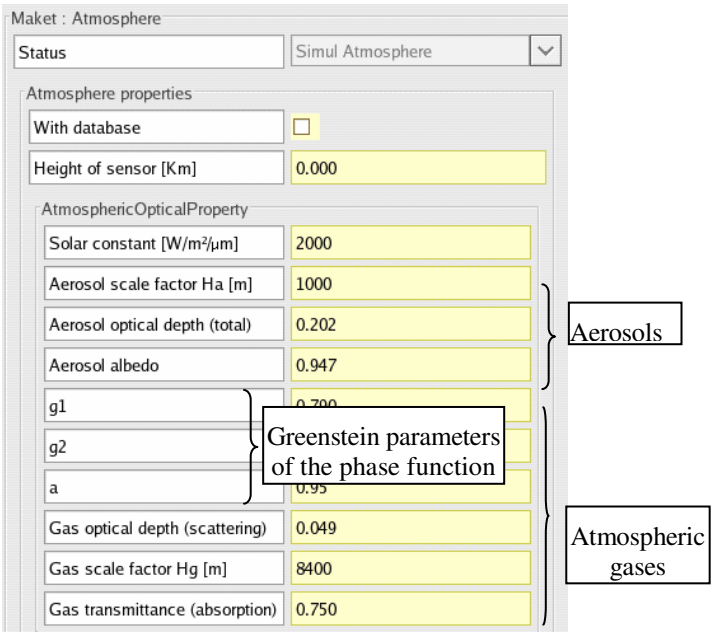


Figure III.30: "Maket: Atmosphere" menu. Case "Atmospheric radiative simulation without database".

- ***Atmosphere with data base***

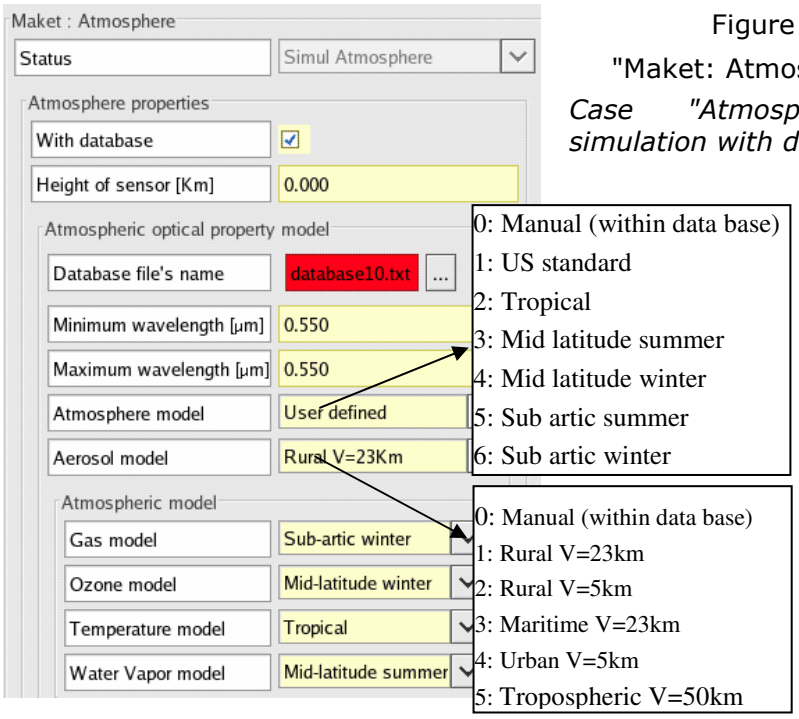


Figure III.31:

"Maket: Atmosphere" menu.

Case "Atmospheric radiative simulation with database"

The user must select:

- *Atmospheric data base and spectral domain*. The spectral domain is needed for computing the appropriate optical parameters with the information from the data base.
- *Atmosphere (gas) model*: available gas models are "Mid-latitude summer", "Sub-artic summer", "Tropical", "Mid-latitude winter", "Sub-artic winter" and "US standard 1976". The option "User defined" sets the vertical profiles of O_3, H_2O, all other gases and temperature from different models.
- *Aerosol model*: models are "Maritime V=23km", "Tropospheric V=50km", "Rural V=5km", "Urban V=5km", "Fog radiation V=0.5km", "Rural V=23km". Term "V" stands for visibility.

The "Manual" option in the menus "gas & aerosols models" allows the user to select user defined profiles (*e.g.*, from radio sounding) are stored in specific columns of the data base.

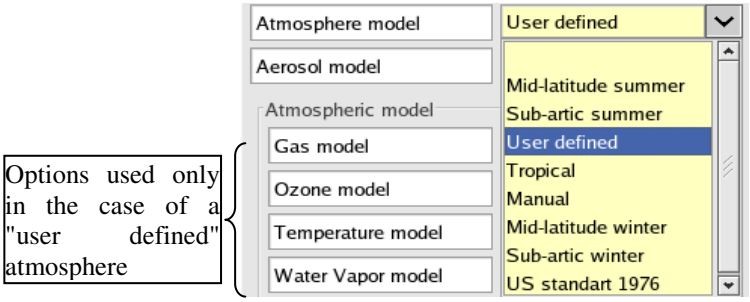


Figure III.32 :

Atmosphere model selection.

"Maket: Atmosphere + data base" menu

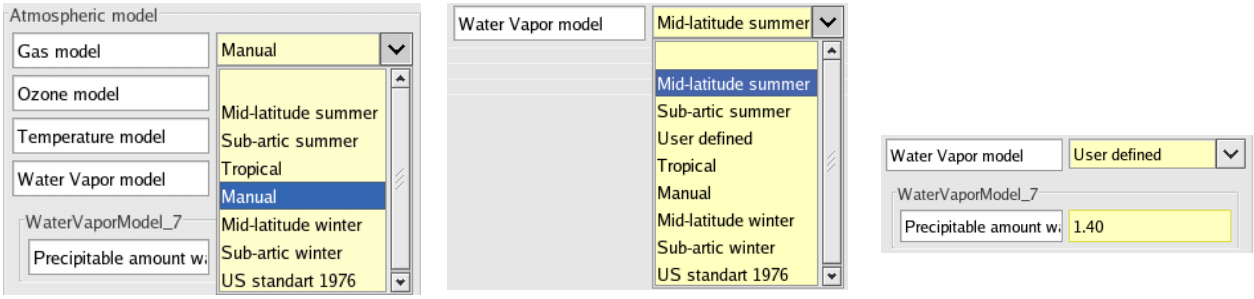


Figure III.33 : "Gas model" and "Water vapor" menus. The "User specified" option for water vapor implies to give the precipitable water vapor (profile proportional to that of US standard).

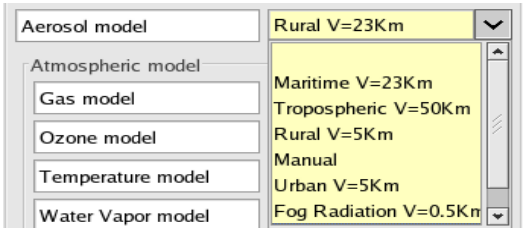


Figure III.34 :

Aerosol model selection.

"Maket: Atmosphere + data base" menu

III.6 DART

III.6.1 DART atmospheric parameters

This menu defines how the scene is illuminated (*cf. "Maket: atmosphere" menu*):

- no illumination,
- pre-defined isotropic or anisotropic illumination,
- illumination that results from atmospheric radiative transfer (with/without data base). The "Maket: atmosphere" menu specifies the characteristics of the atmosphere.

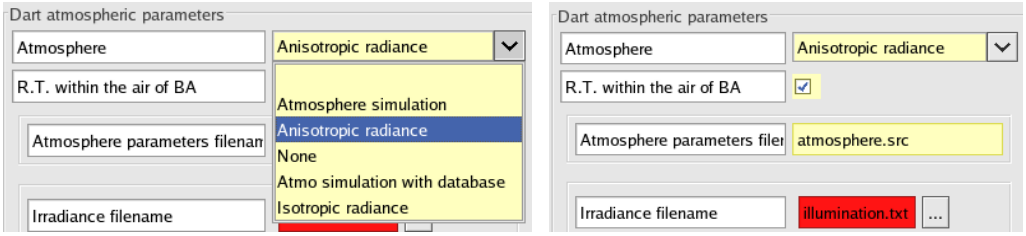


Figure III.35: "DART atmospheric" menu. Case "Anisotropic radiance"

The atmosphere file must be specified if there is radiative transfer in the air of BA. It is computed with the atmosphere specified in the "Maket: atmosphere" menu.

III.6.2 DART input parameters

The user specifies:

- Radiative transfer method: "DART" or "DART + Monte Carlo" (only valid for mode ® mono/XS).
- Name of the file that stores the scene simulation
- Presence of topography, and the topography filename, if there is topography.
- Sun zenith, azimuth angles. For modes "R", "R+T" ("T" if Earth temperatures are computed), starting from an illumination in the visible. Also required for the "Multispectral case".
- Illumination mode: irradiation of the whole scene or a rectangle, with a specified size.
- Acceleration method: Gauss Seidel

- Account of vegetation specular processes (i.e., Fresnel reflectance).
- DART mode: R (reflectance) or T (thermal)
- Propagation and albedo thresholds: they stop low energy rays and simulation (if albedo = cst).
- Number of iterations. We get 1st scattering order simulations if the iteration number is set to 0.
- Radiometric sensor simulation.
- Exactly periodic scene or not exactly periodic scene (for simulating infinite slopes).

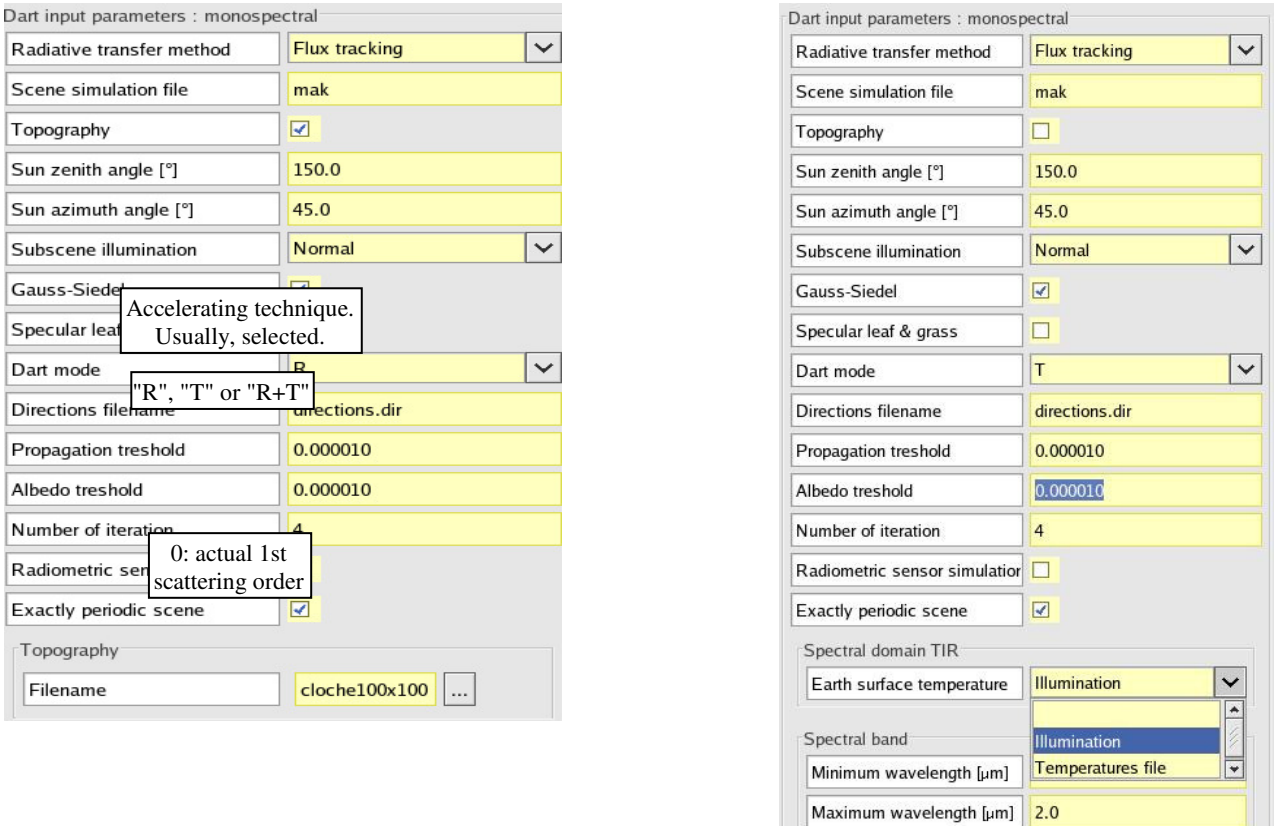


Figure III.36 : "DART monospectral input parameters" menu. a) Mode R. b) Mode T.

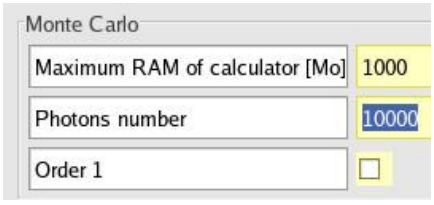


Figure III.37 : "DART Monte Carlo" menu.

- *Available RAM is specified to adapt the possible accuracy.*
- *The photons number N_{ph} per sub cell is specified (for each cell = 25 N_{ph} photons).*

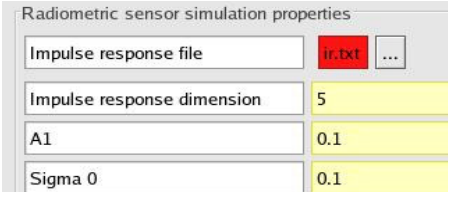


Figure III.38 : "Sensor properties" menu. *It specifies sensor characteristics for simulating actual sensor images.*

Mode T monospectral. The user specifies:

- Scene temperatures. They are computed through a scene illumination in the visible (VIS) domain, or given by a 3-D cell matrix (unique temperature per cell) stored in a file. With

the "illumination" option, temperatures of elements within a same cell can differ. The VIS illumination is simply defined by a SKYL in the VIS ("DART atmospheric parameters" menu).

- In mode "R+T", absolute sun constant is required. It comes from the atmosphere data base.
- the spectral interval.

Case "Multispectral". The user specifies:

- Here, the user specifies here 2 wavelengths λ_1 and λ_2. Spectral bands [λ_{min} λ_{max}] used for the simulations are specified in the "Phase input parameters" menu. DART mode is "R" if $\lambda_{max} < \lambda_1$, "T" if $\lambda_{min} > \lambda_2$, and "R+T" if {$\lambda_{max} > \lambda_1$ and $\lambda_{min} < \lambda_2$}.
- All atmospheres are possible, except "Atmosphere simulation without data base". In mode "R", in the absence of atmosphere simulation, atmosphere illumination is simulated with spectral SKYL, in the "DART atmospheric parameters" menu.
- Parameters associated to modes "R" and "T" are input because a single multispectral simulation can include different modes among "R", "T" and "R+T".

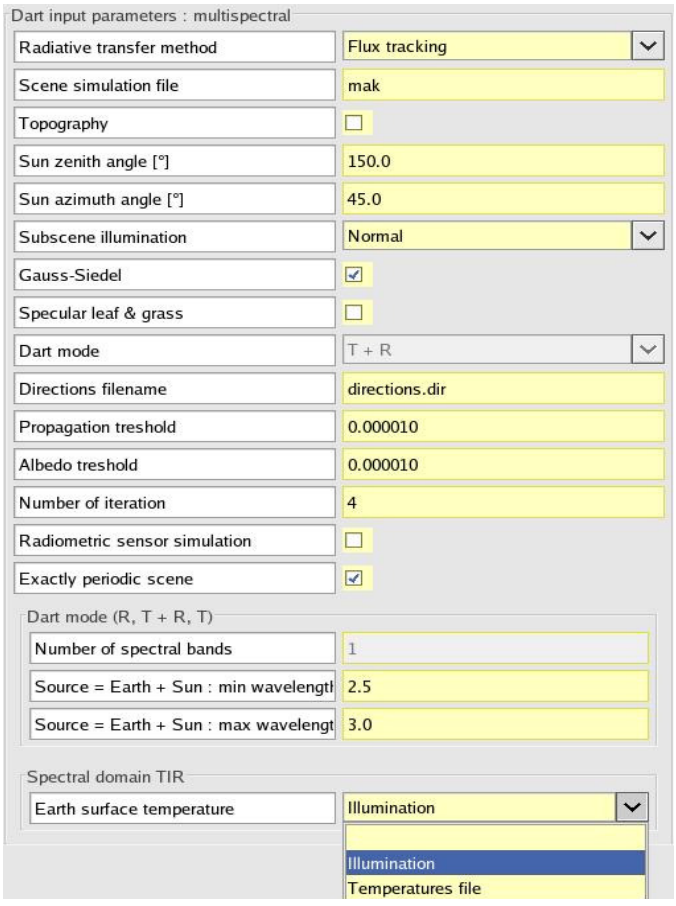


Figure III.39 :
"DART multispectral input parameters" menu.

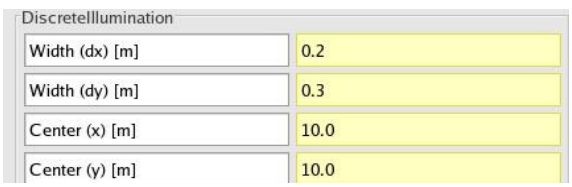


Figure III.40 :
"Discrete illumination" menu.
It specifies the dimensions of the illuminated sub-scene.

III.6.3 DART products

Any DART image is georeferenced. It is a binary file ("mp#" extension) with a header file ("mpr extension) that contains information (numbers of rows and lines). Associated files (extensions "grf" and "gr#") store the association "coordinates (x,y) – (row, line)".

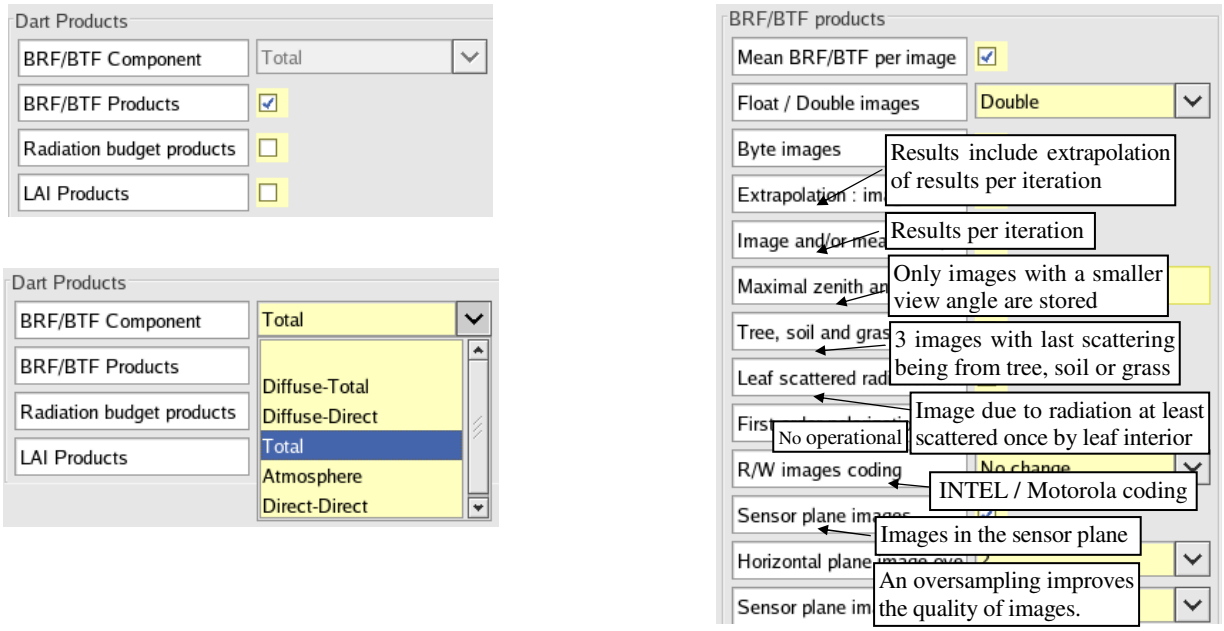


Figure III.41 : "DART BRF/BTF products" menu. Mode (R).

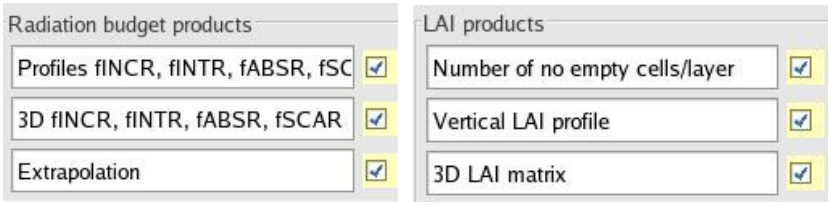


Figure III.42 : "Radiation budget" and "LAI products" menu. Mode (R).
LAI products are simply derived from the computer scene.

III.7 View menu

The View menu (*Figure III.43*) is used to display and save information (format jpg or png):

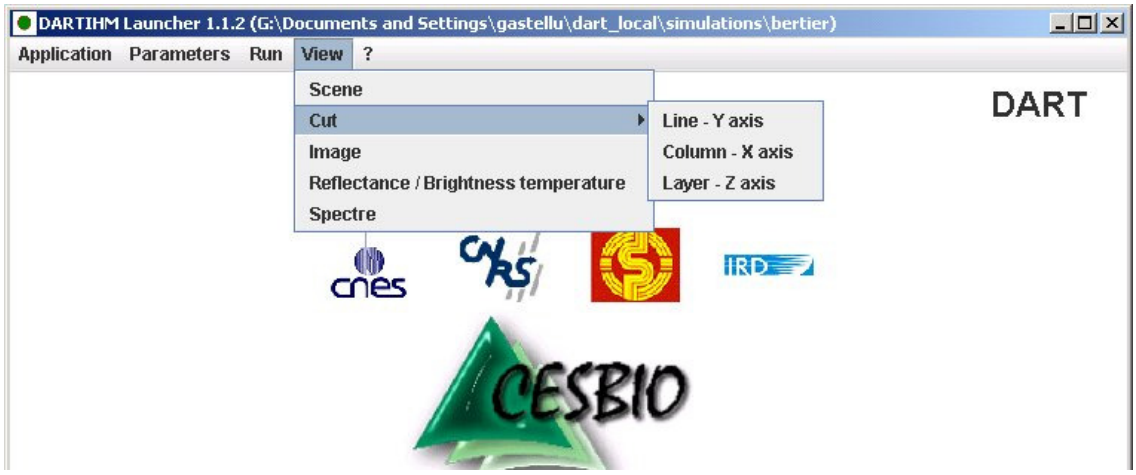


Figure III.43 : "View menu".

1) *3D display of the scene* (Figure III.44),

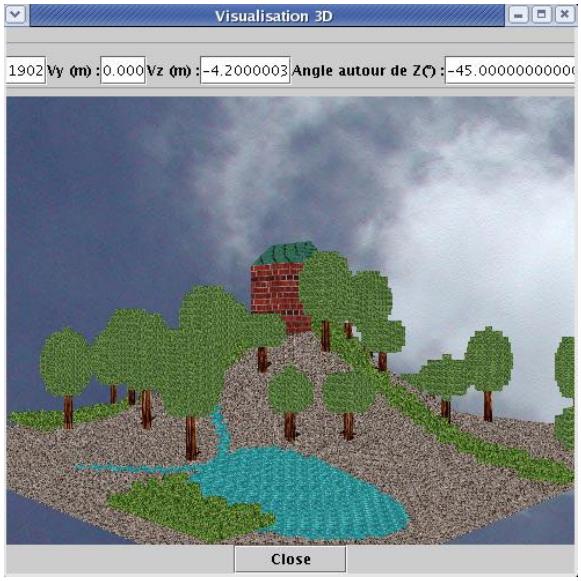


Figure III.44:

3D display of the DART scene with the 3-D viewer.

2) *2D display of the scene* (*Figure III.45*)

It displays 2D sections of the scene (planes xy, yz or xz), with an indication of the nature of the cell under the mouse. Directly for the 2D display, the user can:

- zoom with the "zoom navigator menu",
- change of level within the same section, and change of section (*e.g.*, from xy horizontal plane to yz vertical plane, through the present (y,z) coordinates, with the "cut menu"
- save views (*Figure III.46*)

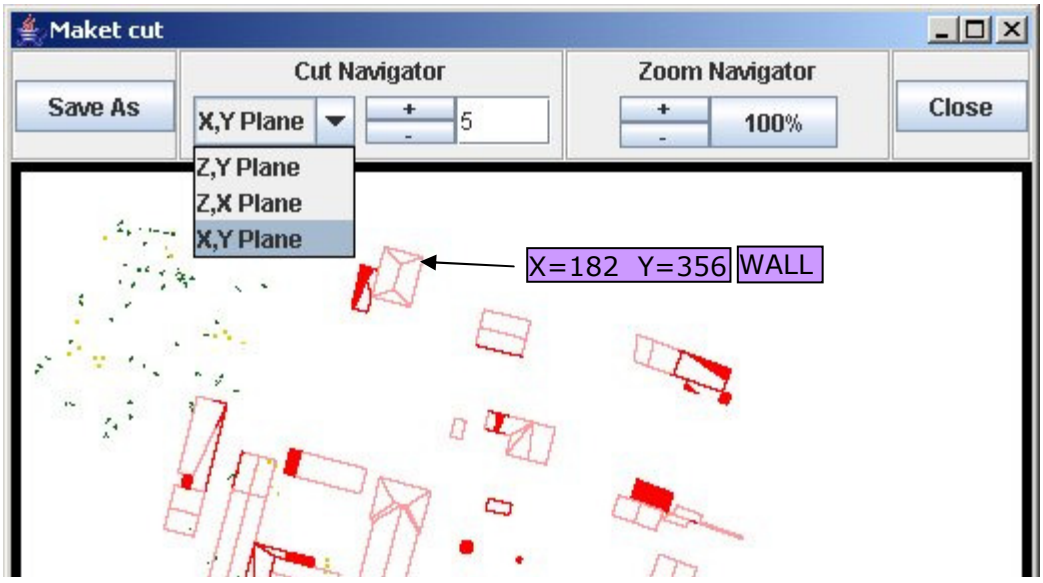


Figure III.45: 2D scene horizontal display.
Coordinates and nature of the scene element under the mouse.

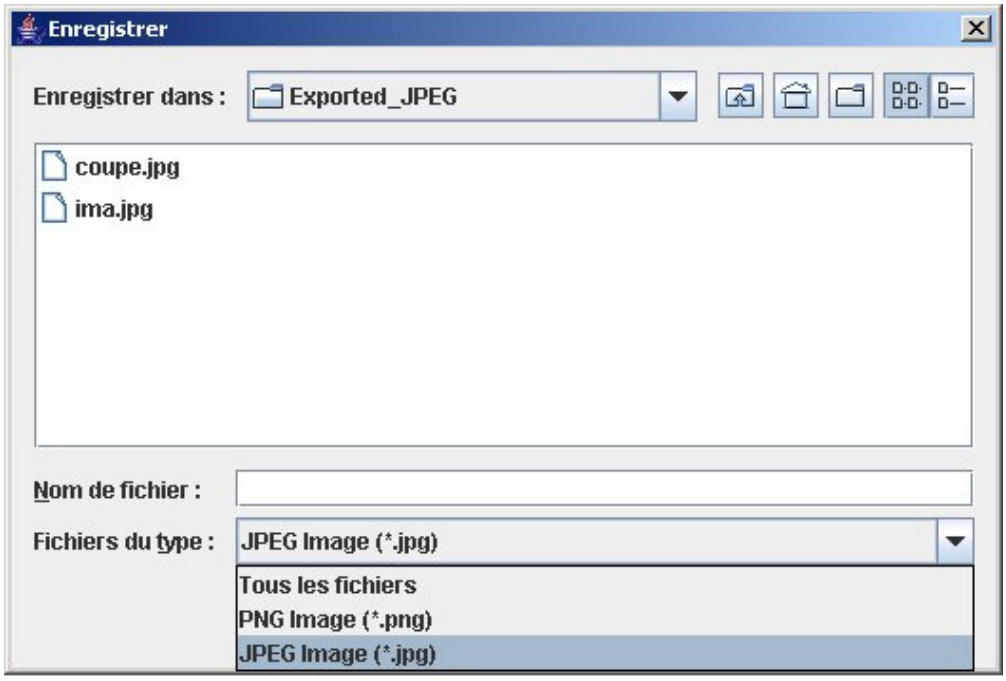


Figure III.46: "save menu". Formats jpg and png.

3) *Display of DART images*

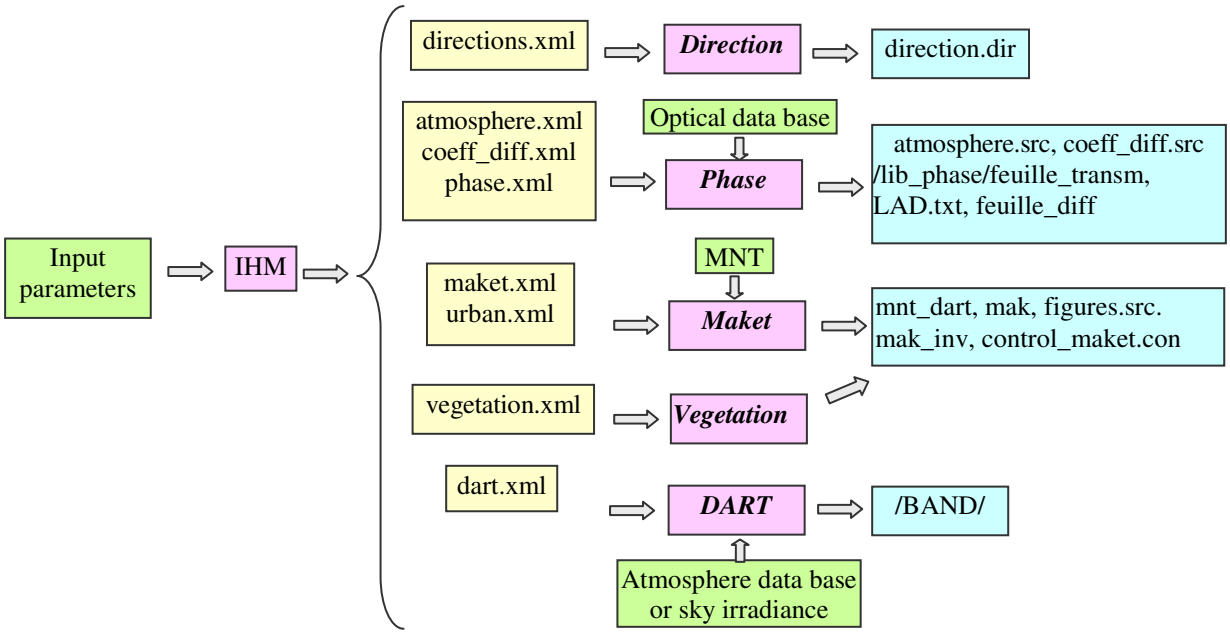
The user specifies the image file name (usually a file with an "mp#" extension. The system automatically reads the associated header file (extension "mpr") that informs about image characteristics (row number, etc.). Images can be saved (*Figure III.46*).

Note: files with "mpr" and "mp#" extensions are image files in the ILWIS format.

4) *Display of reflectance values and brightness temperatures* (under development).

5) *Display of spectra* (under development).

IV Format of files used by DART



mnt_mak (→ DART) : DEM file MNT . It is created by Maket from a DEM file.

mak (→ DART): scene simulation file.

mak_inv: scene vegetation inventory (actual forest coverage, plot LAI and canopy LAI values)

figures.src: file that stores the number of figures, and the coordinates and optical properties of all figures

control_maket.con : general information about vegetation in the scene (includes "mak_inv").

IV.1 File directions.dir

The directions.xml file shown in Table IV-1 specifies that the module "direction" will create ≈2 sectors and ≈95 directions (θ, ϕ), stored in file directions.dir (Table IV-2), without oversampling the hot spot and the sun plane. Directions (0, 0), (180, 0) and sun direction (here: (θ_s=150, ϕ_s=0) are always present. Actually, 111 directions and 6 sectors are created. The sector index indicates the sector to which direction (θ, ϕ) belongs.

```
<?xml version="1.0" encoding="UTF-8" ?>
- <DartFile version="1.0">
  <Directions angleStep="10.0" hotSpotOverSampling="0" numberOfAngularSector="2" numberOfPropagationDirections="95"
              planesOverSampling="0" sunAzimuthAngle="45.0" sunZenithAngle="150.0" />
  </DartFile>
```

θ	Φ	ΔΩ	Sector	θ	Φ	ΔΩ	Sector	θ	Φ	ΔΩ	Sector
0	0	0.03442	0	24	120	0.089044	0	144	300	0.12868	3
12	0	0.068275	0	24	180	0.089044	0	150	0	0.03217	3
12	90	0.068275	0	24	240	0.089044	0	156	0	0.089044	5
12	180	0.068275	0	24	300	0.089044	0	156	60	0.089044	5
12	270	0.068275	0	36	0	0.12868	1	…	…	…	…
24	0	0.089044	0	…	…	…	…	168	270	0.068275	5
24	60	0.089044	0	144	240	0.12868	4	180	0	0.03442	5

Table IV-2: File directions.dir. *(θ_s=150, ϕ_s=0).*

IV.2 File LAD.txt

Phase module computes systematically the uniform (0), spherical (1), erectophile (2), planophile (3), extremophile (4), plagiophile (5), horizontal (6) and vertical (7) LADs (8 LADs). They are stored in the "LAD.txt" file. This file contains also the ellipsoidal (8) or the elliptical (9) LADS, if one of these is required. Phase module stores also the elliptical LAD in the "LAD_ELLIPT.txt" file, if this LAD is specified.

	θ_f	LAD(θ_f)		θ_f	LAD(θ_f)		θ_f	LAD(θ_f)		θ_f	LAD(θ_f)		θ_f	LAD(θ_f)		θ_f	LAD(θ_f)		θ_f	LAD(θ_f)		θ_f	LAD(θ_f)		θ_f	LAD(θ_f)
0	0	0.010989	1	0	0.000152	2	0	0	3	0	0.021978	4	0	0.021739	5	0	0	6	0	1	7	0	0	8	0	0	9	0	0
0	1	0.010989	1	1	0.000457	2	1	0.000007	3	1	0.021971	4	1	0.021713	5	1	0.000027	6	1	0	7	1	0	8	1	0.108552	9	1	0.000066
..	..	.....	...	..	....	...	...	....	....	...	....	....	...	....	....	...	....	....	...	....	....	...	....	....	...	....	....	...	....
0	89	0.010989	1	89	0.017452	2	89	0.021971	3	89	0.000007	4	89	0.021713	5	89	0.000108	6	89	0	7	89	0	8	89	0.002082	9	89	0.215362
0	90	0.010989	1	90	0	2	90	0.021978	3	90	0	4	90	0.021739	5	90	0.000027	6	90	0	7	90	1	8	90	0.379844	9	90	0.003759

Table IV-3: File LAD.txt. Only 1 or none of the ellipsoidal (8) and elliptical (9) LAD is stored.

IV.3 Format of file **.diff*

File *.diff stores scattering coefficients $T(\Omega_{sun},\Omega_i)$ and $T(\Omega_{sector,k},\Omega_i)$ and coefficient $TG(\Omega_i)$ with $k \in$ [1 Number_of_sectors] and $i \in$ [1 Number_of_directions]. The example shown in Table IV-4 is for 6 sectors and 112 directions (θ, ϕ), including sun direction (θ_s=150, ϕ_s=0). SectorDirection 112 is sun direction with a null solid angle (this information is redundant).

	Dir. 1	Dir. 2	Dir. 3	Dir. 4	...	Dir. 109	Dir. 110	Dir. 111	Dir. 112
(θ_s, ϕ_s)	0.001331	0.002421	0.0026	0.002815	...	0.002421	0.0026	0.001331	
Sector 1	0.001409	0.002753	0.002753	0.002753	...	0.002753	0.002753	0.001409	0
Sector 2	0.001065	0.002201	0.002122	0.002025	...	0.002201	0.002122	0.001065	0
Sector 3	0.001065	0.002025	0.002104	0.002201	...	0.002025	0.002104	0.001065	0
Sector 4	0.001066	0.002026	0.002105	0.002202	...	0.002026	0.002105	0.001066	0
Sector 5	0.001065	0.002201	0.002122	0.002025	...	0.002201	0.002122	0.001065	0
Sector 6	0.001409	0.002753	0.002753	0.002753	...	0.002753	0.002753	0.001409	0
TG(Ω)	0.006983	0.013817	0.013817	0.013817	...	0.013817	0.013817	0.006983	

Table IV-4: File *_diff. Coefficients $T(\Omega_s,\Omega_i)$, $T(\Omega_{sector,k},\Omega_i)$ and $TG(\Omega_i)$ with $k \in$ [1 6] and $i \in$ [1 112].

- File *_spec has the same structure as *_diff. It is created if leaf specular reflectance is possible.
- There are as many files *_diff and *_spec as there are leaf species.

The Phase module stores in the directory */lib_phase/*:

- opaque surface: a file tthat contains the discrete phase function of this opaque surface.
- turbid medium: 3 text files that contain transfer functions for scattering (*fonc_fol(j)_diff**q***), for specular and polarized (1 fichier: *fonc_fol(j)_spec**q***), for transmittance (*fonc_fol(j)_trans*), where j is the turbid medium type and q is the spectral band index.

  File *fonc_fol(j)_trans* is computed once, because it is independent of wavelength. It contains $T(j,\Omega_n)_{n=1..N}$ (N = total number of directions).

  File *fonc_fol(j)_diffq* is for wavelength q. It contains $T(j,\Omega_{Soleil},\Omega_V,q)_{v=1..N}$ and $T(j,\Omega_I,\Omega_V)_{I=1..S,v=1..N}$ (S = number of angular sectors).

  File fonc_fol(j)_specq is for wavelength q. It contains in the order $T_S(j,\Omega_{Soleil},\Omega_V,\boldsymbol{q})_{v=1..N}$ (transfer function for specular), $T_P(j,\Omega_S,\Omega_V,\boldsymbol{q})_{v=1..N}$ (transfer function for polarization), $T_S(j,\Omega_I,\Omega_V)_{I=1..S,v=1..N}$, $TG(j,\Omega_V,\boldsymbol{q})_{v=1..N}$, $TG_S(j,\Omega_V,\boldsymbol{q})_{v=1..N}$, $S_1(j,\Omega_S,\Omega_V,\boldsymbol{q})_{v=1..N}$, $S_1(j,\Omega_I,\Omega_V,\boldsymbol{q})_{I=1..S,v=1..N}$, $S_M(j,\Omega_V,\boldsymbol{q})_{v=1..N}$, $p_1(j,\Omega_V,\boldsymbol{q})_{v=1..N}$.

Sub directory ./lib_phase/

- **Turbid medium**

3 files: their names have a root that is a name specific to the type of vegetation j, and an extension that is an abbreviation associated with the 3 physical mechanisms considered:

- "_transm" for transmission. This file contains the geometrical factor related to the function transfer for transmission: $G(j,\Omega_n)_{n=1..N+1}$ *(N = Numberof directions, without sun direction).*

- "_diff" for diffuse. This file contains in the order the transfer functions "diffuse":

$T_d(j,\Omega_s,\Omega_V)_{V=1..N}$, $T_d(j,\Omega_i,\Omega_V)_{i=1..S;V=1..N}$ *(S = Number of angular sectors),* $TG(j,\Omega_V)_{V=1..N}$

- "_spec" for specular (if n_{inf} *or* $n_{sup} \neq 0$*). This file contains in the order:*

$T_s(j,\Omega_s,\Omega_V)_{V=1..N}$ *(specular),* $T_p(j,\Omega_s,\Omega_V)_{V=1..N}$ *(polarised),* $T_s(j,\Omega_i,\Omega_V)_{i=1..S\ ;\ V=1..N}$, $TG(j,\Omega_V)_{V=1..N}$

$TG_s(j,\Omega_V)_{V=1..N}$, $S1(j,\Omega_s,\Omega_V)_{V=1..N}$, $S1_{moy}(j,\Omega_V)_{V=1..N}$, $S_M(j,\Omega_V)_{V=1..N}$, $P1(j,\Omega_s,\Omega_V)_{V=1..N}$

- **Horizontal opaque surface lambertian and specular + Hapke**

Transfer functions for (lambertian + specular) and for polarisation are stored in a file with a specific name: $T_{sol}(j,\Omega_s,\Omega_V)_{V=1..N}$ *(lambertian + specular),* $T_{sol,p}(j,\Omega_s,\Omega_V)_{V=1..N}$ *(polarisation)*

Transfer functions for (Hapke + spéculaire) and for polarisation are stored in a file with a specific name: $T_{Hapke}(j,\Omega_s,\Omega_V)_{V=1..N}$ (Hapke + spécular), $T_{sol,p}(j,\Omega_s,\Omega_V)_{V=1..N}$ (Hapke polarised)

/DATABASE/

This directory contains the atmosphere data base DART (2 text files of resolution 1 and 10 cm^{-1} resulting from Modtran simulation) and spectral reflectance data bases (23 text files extracted the ASTER data base of NAS.

Output directory

batchPhase, LAD.txt, directions.dir(r), coeff_diff.src(r), coeff_diffn.src(w), atmosphere.src(r), atmospheren.src(w)

Turbid medium.

3 files created per spectral channel q and per vegetation type (fonc_fol) j from spectral data base):

*- fonc_fol(j)_trans**:***

The geometric factor, being independent of λ is computed only for the first wavelength.

This file contains $G(j,\Omega_n)_{n=1..N+1}$ *(N = number of directions, but the sun direction).*

*- fonc_fol(j)_diff**q** with q = 0 à Q-1:*

Directory ./lib_phase/

The transfer function for scattering depending on λ, this file contains $T_d(j,\Omega_s,\Omega_V,\mathbf{q})_{V=1..N}$ *and* $T_d(j,\Omega_i,\Omega_V,\mathbf{q})_{i=1..S\ ;\ V=1..N}$ *(S = nombre de secteurs angulaires fixé à 6),* $TG(j,\Omega_V,\mathbf{q})_{V=1..N}$

*- fonc_fol(j)_spec**q** with **q = 0** à **Q-1** (if* $n_{inf}(q)$ *or* $n_{sup}(q) \neq 0$*):*

Transfer functions for specular and polarized depending on λ, this file contains in the order:

$T_s(j,\Omega_s,\Omega_V,\mathbf{q})_{V=1..N}$ *(specular),* $T_p(j,\Omega_s,\Omega_V,\mathbf{q})_{V=1..N}$ *(polarised),* $T_s(j,\Omega_i,\Omega_V,\mathbf{q})_{i=1..S;v=1..N}$, $TG(j,\Omega_v,\mathbf{q})_{v=1..N}$

$TG_s(j,\Omega_V,\mathbf{q})_{V=1..N}$, $S1(j,\Omega_s,\Omega_V,\mathbf{q})_{V=1..N}$, $S1_{moy}(j,\Omega_V,\mathbf{q})_{V=1..N}$, $S_M(j,\Omega_V,\mathbf{q})_{V=1..N}$, $P1(j,\Omega_s,\Omega_V,\mathbf{q})_{V=1..N}$

- **Horizontal opaque surface lambertian and specular + Hapke:**

Names of files = names of transfer functions for (lambertien + specular) and for polarisation derived from the data base:

$T_{sol}(j,\Omega_s,\Omega_V,\mathbf{q})_{V=1..N}$ *(lambertian + spécular),* $T_{sol,p}(j,\Omega_s,\Omega_V,\mathbf{q})_{V=1..N}$ *(polarisation)*

File names = names of transfer functions for (Hapke + specular) and polarisation from the data base:

$T_{Hapke}(j,\Omega_s,\Omega_V,\mathbf{q})_{V=1..N}$ (Hapke + specular), $T_{sol,p}(j,\Omega_s,\Omega_V,\mathbf{q})_{V=1..N}$ (Hapke polarisation)

Figure IV.1: *Files created by the Phase module.*
Mode monospectral (top). Mode multispectral (bottom)

IV.4 Format of **_transm* file

File *_transm stores coefficients $G(\Omega_i)$ for all directions of directions.dir, plus sun direction with a null solid angle. Thus, here this file contains 112 values.

Dir. 1	Dir. 2	Dir. 3	Dir. 4	….	Dir. 109	Dir. 110	Dir. 111	Dir. 112
0.5	0.5	0.5	0.5	….	0.5	0.5	0.5	0.5

Table IV-5: File *_transm. *Spherical LAD. Coefficient G(Ω_i) with $i \in [1\ 112]$. Dir. 112 = sun direction Ω_s with $\Delta\Omega_s = 0$ (redundant* information because Ω_s is already present*).*

IV.5 Format of *.txt (data base "reflectance")

The structure of the data base "reflectance" differs depending on the fact that we deal with opaque materials (surface scattering) or turbid vegetation (volume scattering).

• ***Opaque materials***

1st line: * text that describes the material * (asterisks delimit the comments in the file)

2nd line: *number of available values *

3rd line: *Lambda_min – Lambda_max * λ_{min} λ_{max}

4th line: non spectral Hapke parameters b_0 h b_1 c_1 b_2 c_2 (by default: $b_0 = h = b_1 = c_1 = b_2 = c_2 = 1$)

5th line: *spectral parameters * lambda Ro n A_1 α_1 ω A_2 α_2

Col. 1: wavelengths. Col. 2: lambertian spectral reflectance.

Col. 3: refraction index (*e.g.*, 1.4) for mode "lambertian + specular".

Col. 4: A (*e.g.,* 1000) for mode "lambertian + specular".

Col. 5: Alpha (*e.g.,* 0.2 rad) for mode "lambertian + specular".

Col. 6: spectral albedo, initialized with 30(%), for "Hapke + specular".

Col. 7: A (*e.g.,* 1000) for "Hapke + specular".

Col. 8: Alpha (*e.g.,* 0.2) for "Hapke + spéculaire".

```
* text that describes the material *
* Number of Lambda pertinent values * 491
* Lambda_min - Lambda_max * 0.42  14
* Hapke parameters: Bo - h - b1 - c1 - b2 - c2  *  1 1 1 1 1
* Lambda - Ro - Refraction Index - A - Alpha - ω_Hapke - A_Hapke_spec - Alpha_Hapke_spec *
  0.42     4.522          1.4      1000   0.2        30          1000              0.2
                  …
  14      4.029     1.4     1000     0.2     30     1000     0.2
```

Lambda and Ro (lambertian reflectance) are from the Aster data base.

All other parameters are defined by the user

Figure IV.2 : File **.text for opaque material.*

• ***Vegetation materials***

1st line: * text that describes the material * (asterisks delimit the comments in the file)

2nd line: *number of available values *

3rd line: * Non spectral leaf parameters * LAD – Leaf size - type of rugosity sup - type of rugosity inf *

By default: LAD = 1 (spherical), Dim = 0,05 (m), Type_RS = 0(cst), Type_RI = 0

4th line: *Spectral parameters* λ - $R_{abaxial}$ - $R_{adaxial}$ - transmittance - n_{inf} - n_{sup} - Ko_{inf} - Ko_{sup} - k_{inf} - k_{sup}*

Wavelength, abaxial reflectance, adaxial reflectance, transmittance, refraction index inf and sup (*e.g.*, 1.4), rugosity inf and sup (*e.g.*, 0.9) and rugosity index inf and sup (*e.g.*, 0.2).

At least, 23 text files derived from the reflectance data base (*http://speclib.jpl.nasa.gov*) from 0.3µm to 15µm, are in the DATABASE directory:

argile.txt, asphalte_chaussee.txt, goudron.txt, tuiles.txt, beton_de_construction.txt, beton_murs.txt, brique_rouge.txt, eau.txt, feuille_conifere.txt, feuille_feuillu.txt, glace.txt, herbe.txt, herbe_seche.txt, neige.txt, peinture_noire.txt, pin_construction.txt, sable_blanc_de_dune.txt, terre_graveleuse.txt, terre_sablonneuse.txt, toit_asphalte.txt, toit_en_aluminium.txt, vitre.txt

```
*  text that describes the material *
* Number of Lambda pertinent values : * 550
* Lambda_min - Lambda_max : * 0.302  14
* Leaf parameters: LAD - Foliar dimension(m) - Upper type of roughness [0/1:cst/var] - Lower type of
    roughness * 1 (spherical) 0.05  0  0
* Lambda - Lower reflectance - Upper reflectance - Transmittance - n_inf - n_sup - Koinf [0 1] - Kosup -
    Ind_rugInf [0.1 0.3] - Ind_rugSup *
     0.302   2.9582    2.9582    2.9582    1.4    1.4    0.9
                        ……..
```

Base ASTER $\Rightarrow R_{abaxial}, R_{adaxial}$, *transmittance*

User $\Rightarrow n_{inf}, n_{sup}$, *Koinf, Kosup, Ind_rugInf, Indrug_Sup*

Figure IV.3 : File **.text for vegetation material.*

In the case of Q spectral bands, the module *Phase creates*:

- Q files coeff_diff.src (coeff_diff0.src, coeff_diff1.src,...), starting from the files within DATABASE.
- Q files atmosphere.src (atmosphere0.src, atmosphere1.src, etc.), starting from the atmosphere data base.'

Default "Atmosphere" data base is database10.txt (spectral resolution: 10 cm^{-1}). One can work with smaller spectral resolutions. For example, the database1.txt file (1 cm^{-1}) can simply replace the database10.txt file in DATABASE and also in function calcul_constante_solaire() of phase.c.

IV.6 Format of *atmosphere.src* file

The module "phase" creates an atmosphere.src file, from an atmosphere.xml file (Figure IV.4)

```
<?xml version="1.0" encoding="UTF-8" ?>
- <DartFile version="1.0">
  - <Atmosphere notYetProcessedByPhase="1">
    - <AtmosphereProperties database="1" heightOfSensor="20">
      - <AtmosphericOpticalPropertyModel aerosolModel="1" atmosphericModel="7" databaseFileName="database10.txt"
                  spectralRangeLambdaMax="0.6" spectralRangeLambdaMin="0.550">
        <AtmosphericModel_7 ozoneModel="4" scaleFactorModel="6" temperaturesModel="2" waterVaporModel="3" />
       </AtmosphericOpticalPropertyModel>
     </AtmosphereProperties>
   </Atmosphere>
  </DartFile>
```

Figure IV.4: *Example of atmosphere.xml file (with data base)*

* Already processed by Phase * 1	* N2O Transmittance (absorption)* 0.996820
* Without/with database * 1	* O2 Transmittance (absorption)* 0.996820
* Database file name * database10.txt	* N2 Transmittance (absorption)* 0.996820
* Spectral sampling * 0.550000 0.600000	* O3 Transmittance (absorption)* 0.954105
* Type of model atmosphere [0 7]* 7	* H2O Transmittance (absorption)* 0.995023
* Scale factor model[0 6] - Ozone model[0 6] - Temperatures model[0 6] - Water vapor model[0 7] * 6 4 2 3	* Ozone distribution (nb layers)* 32 0.000000 1.000000 0.006722

* Type of aerosol model [0 6] * 1	1.000000 2.000000 0.006050
* Height of sensor (km) * 20.000000	2.000000 3.000000 0.005498
* TOA solar irradiance(W/m2/um) * 1889.524658	3.000000 4.000000 0.005498
* Aerosol scale factor (m) * 2000.000000	……..
* Total aerosols optical depth * 0.309879	45.000000 50.000000 0.007419
* Aerosol albedo * 0.981135	50.000000 70.000000 0.009123
* g1 [0 1] * 0.790000	70.000000 100.000000 0.000127
* g2 [0 1] * 0.400000	* Temperatures distribution * 33
* a [0 1] * 0.950000	0.000000 299.700012
* Gas optical depth (scattering)* 0.085122	1.000000 293.700012
* Gas Scale Factor (scattering) * 7552.799805	2.000000 287.700012
* H20 Scale Factor * 3471.800049	……
* CO2 Scale Factor * 7542.899902	24.000000 219.199997
* CO Scale Factor * 5713.799805	25.000000 221.399994
* CH4 Scale Factor * 7061.100098	30.000000 232.300003
* N2O Scale Factor * 7052.899902	35.000000 243.100006
* O2 Scale Factor * 7531.500000	40.000000 254.000000
* N2 Scale Factor * 3914.399902	45.000000 264.799988
* CO2 Transmittance (absorption)* 0.996820	50.000000 270.200012
* CO Transmittance (absorption)* 0.996820	70.000000 218.899994
* CH4 Transmittance (absorption)* 0.996820	100.000000 190.699997

Figure IV.5 : *Example of atmosphere.src file (associated to*

```
<?xml version="1.0" encoding="UTF-8" ?>
- <DartFile version="1.0">
  - <Atmosphere notYetProcessedByPhase="1">
    - <AtmosphereProperties database="1" heightOfSensor="20">
      - <AtmosphericOpticalPropertyModel aerosolModel="1" atmosphericModel="7" databaseFileName="database10.txt"
                  spectralRangeLambdaMax="0.6" spectralRangeLambdaMin="0.550">
        <AtmosphericModel_7 ozoneModel="4" scaleFactorModel="6" temperaturesModel="2" waterVaporModel="3" />
       </AtmosphericOpticalPropertyModel>
     </AtmosphereProperties>
   </Atmosphere>
  </DartFile>
```

Figure IV.4 *)*

The format of each line of the file is a comment between asterisks followed of one or more parameters separated by spaces. To remain compatible with the other atmosphere options of DART, the *atmosphere.src* file is always created, even if there is no data base. Then, it contains only one line of comment: * No Atmosphere simulation * -1

* Already/Not yet processed by phase *	0/1
* Without/with database *	0/1
(if without/with database = 1)	
* Database file name *	database10.txt
* Spectral sampling *	2.0 2.5
* Type of model atmosphere [0 7] *	7
(if Type of model atmosphere = 7)	
* Scale Factor model[0 6] - Ozone model[0 6] - Temperatures model[0 6] - Water Vapor model[0 7] *	1 1 1 7
(if Vapor model = 7)	
* Precipitable water amount (cm) *	1.4
* Aerosol model [0 x] *	1
(if without/with database = 0)	
* Solar Illumination(W.m-2.um-1) *	2000
* Aerosols Scale Factor *	2000
* Aerosols Optical Depth *	0.202
* g1 [0 1] *	0.790
* g2 [0 1] *	0.4
* a [0 1] *	0.95
* Gas Optical Depth (diffusion) *	0.049
* Gas Scale Factor (diffusion) *	8454.9
* H20 Optical Depth *	2402.5
* CO2 Optical Depth *	8467.9
* CO Optical Depth *	6243.7
* CH4 Optical Depth *	8192.5
* N2O Optical Depth *	8108.9
* O2 Optical Depth *	8449.5
* N2 Optical Depth *	4639.6
* CO2 Transmittance (absorption) *	0.3354
* CO Transmittance (absorption) *	1.0
* CH4 Transmittance (absorption) *	1.0
* N2O Transmittance (absorption) *	0.9998

* Aerosols albedo * 0.947 * g1 [0 1] * 0.790 * g2 [0 1] * 0.4 * a [0 1] * 0.95 * Gas Optical Depth * 0.049 * Gas Scale Factor * 8000 * Gaseous Transmittance * 0.750 ***(//part written by phase.c (if data=1)//)*** ***(if without/with database = 1)*** * Solar Illumination(W.m-2.um-1) * 2000 * Aerosols Scale Factor * 2000 * Aerosols Optical Depth * 0.202 * Aerosols albedo * 0.947	* O2 Transmittance (absorption) * 1.0 * N2 Transmittance (absorption) * 1.0 * O3 Transmittance (absorption)* 1.0 * H2O Transmittance (absorption)* 0.8517 * Ozone distribution (nb layers) * 32 0 0.006558 1 0.006558 *(…)* * Temperatures distribution * 33 0 288.2 1 281.7 *(…)*

Figure IV.6: *General structure of atmosphere.src file*

IV.7 Atmosphere data base

```
DATABASE FORMAT
Number of gas models                7
Number of aerosol models            7
Number of altitudes of O3 profile   32
Number of altitudes of temperature  33
Number of λ for gas transmittance   3267
Number of liquid H2O values         17

SPECTRAL SAMPLING
nu_max   33327    lambda_min   0.300057
nu_min   667      lambda_max   14.992504
freq_incr 10

AEROSOLS PARAMETERS
model   manual    RURALV23   RURALV5   MARITV23   URBANV5   TROPOV50   FOGRV05
H_p     0.0       2000.0     2000.0    2000.0     2000.0    2000.0     2000.0
g1_p    0.0000    0.7900     0.7900    0.7900     0.7900    0.7900     0.7900
g2_p    0.0000    0.4000     0.4000    0.4000     0.4000    0.4000     0.4000
a_p     0.0000    0.9500     0.9500    0.9500     0.9500    0.9500     0.9500

UNIFORMLY MIXED GASES PARAMETERS
alpha  0.0086   beta 4.1303
model   manual  USSTD76  TROPICAL  MIDLATSUM  MIDLATWIN  SUBARCSUM  SUBARCWIN
H_m     0.0     8454.9   8835.3    8814.5     7972.3     8424.1     7552.8
H_H2O   0.0     2402.5   2167.4    2087.9     2434.5     2289.4     3471.8
H_CO2   0.0     8467.9   8846.7    8653.6     7997.0     8415.3     7542.9
H_CO    0.0     6243.7   6393.4    6307.9     5957.0     6195.8     5713.8
H_CH4   0.0     8192.5   8535.5    8025.3     7485.4     7795.0     7061.1
H_N2O   0.0     8108.9   8463.9    7989.9     7459.6     7449.0     7052.9
H_O2    0.0     8449.5   8847.4    8644.3     7971.6     8424.2     7531.5
H_N2    0.0     4639.6   4845.1    4694.1     4259.4     4567.3     3914.4

OZONE: CUMULATIVE AMOUNTS AND DISTRIBUTION
Z1(KM) Z2(KM) manual    USSTD76   TROPICAL  MIDLATSUM  MIDLATWIN  SUBARCSUM  SUBARCWIN
0      1      0.000000  0.006558  0.008132  0.007508   0.006722   0.005979   0.004661
-------------------------------------
24     25     0.000000  0.043723  0.049540  0.041565   0.040334   0.042038   0.037826
25     30     0.000000  0.206903  0.263277  0.213186   0.187265   0.193216   0.164728
-------------------------------------
45     50     0.000000  0.010384  0.011341  0.010606   0.007419   0.009831   0.006077
50     70     0.000000  0.012805  0.014831  0.013944   0.009123   0.012533   0.007516
70     100    0.000000  0.000150  0.000200  0.000266   0.000127   0.000277   0.000161

TEMPERATURES
Z(KM)  manual  USSTD76 TROPICAL MIDLATSUM MIDLATWIN SUBARCSUM  SUBARCWIN
0      0.0     288.2   299.7    294.2     272.2     287.2      257.2
-----------------------------------
24     0.0     220.6   219.2    223.9     215.2     226.6      211.8
25     0.0     221.6   221.4    225.1     215.2     228.1      211.2
30     0.0     226.5   232.3    233.7     217.4     235.1      216.0
35     0.0     236.5   243.1    245.2     227.9     247.2      222.3
```

```
-----------------------------------
50     0.0      270.7   270.2    275.7      265.7      277.2       259.3
70     0.0      219.6   218.9    218.1      230.7      216.6       245.4
100    0.0      195.1   190.7    190.5      218.6      190.4       218.5
SPECTRAL TRANSMITTANCE OF ABSORBING GASES AND WATER VAPOR
ν λ Eλ τp τp τp τp τp τp τp ωp ωp ωp ωp ωp ωp ωp TCO2 TCO2 TCO2 TCO2 TCO2 TCO2 TCO2 TCO . . .
TCO TCH4 . . . TCH4 TN2O . . . TN2O TO2 . . . TO2 TN2 . . . TN2 TO3 . . . TO3 TH2O . . . . . TH2O
(cm-1) (μm) (W.m-2.μm-1) manual RURALV23 RURALV5 MARITV23 URBANV5 TROPOV50 FOGRV05 manual
RURALV23 RURALV5 MARITV23 URBANV5 TROPOV50 FOGRV05 manual USSTD76 TROPICAL MIDLATSUM
MIDLATWIN SUBARCSUM SUBARCWIN .... manual USSTD76 TROPICAL MIDLATSUM MIDLATWIN SUBARCSUM
SUBARCWIN d=0.1 d=0.2 d=0.3 d=0.4 d=0.6 d=0.8 d=1.0 d=1.4 d=1.8 d=2.2 d=2.6 d=3.0 d=3.4
d=3.8 d=4.2 d=4.6 d=5.0
667    14.992504  5.15E-02  0.0000   0.0163   0.0677    0.0218    0.0881   0.0032.....
-----------------------------------
33327  0.300057   3.38E+02  0.0000   0.5736   2.0479    0.4652    1.9386   0.2917.....
```

Table IV-6: *Atmosphere data base 10cm^{-1} (source: Modtran 3)*

IV.8 Format of the irradiance file that specifies the Earth scene irradiance

θ	Φ	ΔΩ	Irradiance	θ	Φ	ΔΩ	Irradiance	θ	Φ	ΔΩ	Irradiance
0	0	0.03442	0	24	120	0.089044	0	144	300	0.12868	
12	0	0.068275	0	24	180	0.089044	0	150	0	0.03217	
12	90	0.068275	0	24	240	0.089044	0	156	0	0.089044	
12	180	0.068275	0	24	300	0.089044	0	156	60	0.089044	
12	270	0.068275	0	36	0	0.12868	0	…	…	…	…
24	0	0.089044	0	…	…	…	…	168	270	0.068275	
24	60	0.089044	0	144	240	0.12868		180	0	0.03442	

Table IV-7: *File of incident BOA irradiance*.

Its structure is identical to that of the IIDAq.out file. Its last line is a comment between asterisks followed by the value of sun BOA illumination in W/m^2/m(λ). In multispectral mode, all files must have the same name followed by the number of the spectral interval.

IV.9 Format of files coeff_diff.xml and .src

```
<?xml version="1.0" encoding="UTF-8" ?>
- <DartFile version="1.0">
  - <Coeff_diff>
    - <OpticalFunctions>
      - <LambertianMonoFunctions>
          <LambertianMono ident="sol" parameters="1" ro="0.33" roStDev="0.000" />
          <LambertianMono ident="tronc" parameters="1" ro="0.2" roStDev="0.000" />
          <LambertianMono ident="toit" parameters="1" ro="0.3" roStDev="0.000" />
          <LambertianMono ident="mur" parameters="1" ro="0.3" roStDev="0.000" />
        </LambertianMonoFunctions>
        <LambertianSpecularMonoFunctions />
        <HapkeSpecularMonoFunctions />
        <PhaseMonoFunctions />
        - <LeafPhaseMonoFunctions>
        - <LeafPhaseMono dimFoliar="0.01" ident="feuille" indRefracInf="1.40" indRefracSup="1.40"
          koInf="1" koSup="1" lad="1" parameters="1" rhoMoy="0.500046" rhoMoySpec="0"
          roInf="0.30" roSup="0.30" tMax="310" tMin="300" to="0.20" typeRugositeInf="0"
          typeRugositeSup="0">
```

```
                    <DirectionalClumpingIndexProperties clumpinga="0" clumpingb="0" omegaMax="0"
                omegaMin="1" />
            </LeafPhaseMono>
            </LeafPhaseMonoFunctions>
            <LambertianMultiFunctions />
            <LambertianSpecularMultiFunctions />
            <HapkeSpecularMultiFunctions />
            <PhaseMultiFunctions />
            <UnderstoryMultiFunctions />
        </OpticalFunctions>
    - <Temperatures>
            <Soil tMax="310.0" tMin="300.0" />
            <Water tMax="310.0" tMin="300.0" />
            <Roads tMax="310.0" tMin="300.0" />
            <OpaquePlots tMax="310.0" tMin="300.0" />
            <Roofs tMax="310.0" tMin="300.0" />
            <Walls tMax="310.0" tMin="300.0" />
            <Trunks tMax="310.0" tMin="300.0" />
            <BoundingWalls temperature="300.0" />
        </Temperatures>
    </Coeff_diff>
</DartFile>
```

Figure IV.7: *Example of coeff_diff.xml file*

```
*Nb Lambertien -  Nb Lambertian + Specular - Nb Hapke + Specular - Nb Phase for opaque surfaces - Nb Leaf Phase *
4 0 0 0 1

* Lambertian .                                   The index 0/1 indicates if the computation of "mean
Parameters : 0/1 - Name - Ro - Ecart-Type *      reflectance" and/or transfer function already took place
1  sol 0.330000 0.000000
1  tronc 0.200000 0.000000
1  toit 0.300000 0.000000
1  mur 0.300000 0.000000

* Lambertian + Specular.
Parameters : 0/1 - File Name - Ro - A - Alpha - Refraction Index - Albedo moy - Albedo spec *

* Hapke + Specular.
Parameters : 0/1 - Name - w - B0 - b1 - b2 - c1 - c2 - h - A - Alpha - Refraction Index - Albedo moy *

* Phase.
Parameters : 0/1 - File Name - Number of parameters
 if this number is 4 (Lambertan + Specular) :
- Ro - A - Alpha - Refraction Index - Albedo moy
 if this number is 10 (Hapke + Specular) :
-Albedo - B0 - b1 - b2 - c1 - c2 - h - A - Alpha - Refraction Index - Albedo moy *

* Understory.
Parameters : 0/1 - File Name - omegaMin - omegaMax - clumpingA - clumpingB - LAD - (Ellipsoidal : ALA - Elliptical :
Thetam - Eccentricity) - Dim Foliar - RoSup - RoInf - To - IndRefracInf - IndRefracSup - TypeRugositeInf - KoInf -
(Ind_RugInf) - TypeRugositeSup - KoSup - (Ind_RugSup) - Albedo moy Albedo spec *
1 feuille 1.000000 0.000000 0.000000 0.000000 1 0.010000 0.300000 0.300000 0.200000 1.400000 1.400000 0 1.000000 0
1.000000  0.500046 0.000000
```

```
*Tmin, Tmax for soil :                  * 300.000000 310.000000
*Tmin, Tmax for water :                  * 300.000000 310.000000
*Tmin, Tmax for roads :                  * 300.000000 310.000000
*Tmin, Tmax for opaque plots :            * 300.000000 310.000000
*Tmin, Tmax for roofs :                 * 300.000000 310.000000
*Tmin, Tmax for walls :                 * 300.000000 310.000000
*Tmin, Tmax for Trunks :                 * 300.000000 310.000000
*Temperature for bounding walls:          * 300.000000
*Tmin, Tmax for leaf phase function nb 0:  * 300.000000 310.000000
```

These temperatures are necessary for DART mode (T).

Figure IV.8: *Example of coeff_diff.src file. Monospectral mode.*

In multispectral mode with Q bands, there are Q coeff_diff.src files, and for each one, there are 2 additional lines at the beginning of the file: spectral band and sun constant (computed with the atmosphere data base).

IV.10 Format of urban.xml file

```
<?xml version="1.0" encoding="UTF-8" ?>
- <DartFile version="1.0">
  - <Urban>
    - <Buildings>
      - <Building>
        - <WallProperties sameWall="1">
          <OpticalPropertyLink ident="mur" indexFctPhase="3" type="0" />
            </WallProperties>
        - <RoofProperties sameRoof="1">
            <OpticalPropertyLink ident="toit" indexFctPhase="2" type="0" />
          </RoofProperties>
        - <House typeRoof="2">
          - <Wall>
            - <Polygon3D>
                <Point3D x="10.00" y="10.00" z="3" />
                <Point3D x="15.00" y="10.00" z="4" />
                <Point3D x="15.00" y="15.00" z="5" />
                <Point3D x="10.00" y="15.00" z="6" />
              </Polygon3D>
            - <OpticalProperties>
                <OpticalPropertyLink ident="mur" indexFctPhase="3" type="0" />
              = <OpticalPropertyLink ident="mur" indexFctPhase="3" type="0" />
                <OpticalPropertyLink ident="mur" indexFctPhase="3" type="0" />
                <OpticalPropertyLink ident="mur" indexFctPhase="3" type="0" />
              </OpticalProperties>
            </Wall>
          - <RoofPlate height="4">
            - <Polygon3D>
                <Point3D x="10.00" y="10.00" z="4" />
                <Point3D x="15.00" y="10.00" z="6" />
                <Point3D x="15.00" y="15.00" z="9" />
                <Point3D x="10.00" y="15.00" z="8" />
              </Polygon3D>
            - <OpticalProperties>
                <OpticalPropertyLink ident="toit" indexFctPhase="2" type="0" />
                <OpticalPropertyLink ident="toit" indexFctPhase="2" type="0" />
                <OpticalPropertyLink ident="toit" indexFctPhase="2" type="0" />
                <OpticalPropertyLink ident="toit" indexFctPhase="2" type="0" />
                <OpticalPropertyLink ident="toit" indexFctPhase="2" type="0" />
              </OpticalProperties>
            </RoofPlate>
          </House>
        </Building>
      </Buildings>
```

```
        <Roads />
        <SmallWalls />
      </Urban>
  </DartFile>
```

Figure IV.9: *Example of urban.xml file.* 2 points (x,y,z) for classic roof, 4 points (x,y,z) for plate roof and complex roof. Coordinate z is the height relative to local DEM

```
1027
1 18.478975 28.478975 6.250000 18.478975 28.021025 6.250000 18.478975 28.478975 9.102592 1.000000 0.000000 0.000000 0 1 11
0 18.250000 27.750000 6.950275 18.250000 28.250000 6.801988 18.750000 28.250000 7.089921 -0.483329 0.248917 0.839305 0 0 11
0 18.250000 27.750000 6.950275 18.750000 27.750000 7.244261 18.750000 28.250000 7.089921 -0.489807 0.257144 0.833046 0 0 11
  .....
```

Figure IV.10: *Example of figure.src file.* "Index that specifies if it is a triangle or a parallelogram - (x,y,z) coordinates of 3 points - (x,y,z) coordinates of the unit normal vector, type of scatterer - Index for the specified type of scatterer - Type of surface (road, etc.),

IV.11 Format of files vegetation.xml and associated files

```
<?xml version="1.0" encoding="UTF-8" ?>
- <DartFile version="1.0">
  - <Vegetation isVegetation="1">
    - <VegetationProperties coverLandMapDescFileName="descCOS.xml" presenceOfTopography="0" selectSubZone="1"
        spectralBandNumber="3" temperature="0">
        <SpectralBandProperties maxWavelength="0.550" minWavelength="0.500" />
        <SelectSubZoneProperties columnNbSubZone="50" columnOfTopLeftPixel="1" lineNbSubZone="50"
          lineOfTopLeftPixel="1" />
        <SpectralBandProperties maxWavelength="0.68" minWavelength="0.61" />
        <SpectralBandProperties maxWavelength="0.89" minWavelength="0.79" />
      </VegetationProperties>
    </Vegetation>
</DartFile>
```

Figure IV.11: *Example of vegetation.xml file.*

The file **descCOS.xml** must already exist and be located in the directory ***Input***. It must be edited manually.

```
- <DartVegCosDescriptor>
    <RasterCOSInformation nbLi="50" nbCol="50" pixelByteSize="1" pixelSize="20" rawFilename="new_3x3" />
    <ClassCOSInformation classFilename="17juil_newlai_sol.txt" />
</DartVegCosDescriptor>
```

Figure IV.12: *Example of desCOS.xml file.*

*Buildings	3	1	0	0	Tiles.txt	0	0	0	0	0	0
Wheat	5	1	0	0	Chaume.txt	0	0	0	0	0	0
Deciduous	13	1	2	0	Sol5a.txt	Decidious.txt	2.016114	15	0	0	0	0
Friche	80	1	2	0	Sol5a.txt	Grass.txt	1.180458	0.5	0	0	0	0
Jachere	118	1	2	0	Sol5a.txt	Grass.txt	0.472370	0.5	0	0	0	0
Lac	1	1	0	0	Water.txt	0	0	0	0	0	0	0

Mais	7	1	2	0	Sol5a.txt	Decidious.txt	2.420900	1.8	0	0	0	0
Poplars	17	1	2	0	Sol5a.txt	Decidious.txt	0.795875	10	0	0	0	0
Pasture	41	1	2	0	Sol5a.txt	Grass.txt	0.863473	0.5	0	0	0	0

Figure IV.13: *Example of file that describes the land cover map (soil and/or vegetation optical properties, with possibly vegetation structure).*

IV.12 Format of result files

```
- Name of scene file         = mak
- Name of MNT file           = cloche100x100.dart
- Size of an elementary cell = 0.500000 m 0.500000 m  0.500000m
- Scene size                 = 50.000000 m 50.000000 m  21.000000m
- Nli Ncol Nalt              = 100   100   42
- Sun direction  teta = 150.000000 phi = 45.000000
- Prise en compte de l'acceleration de Gauss-Siedel.
- Pas de calcul de sp?éculaire et polarisation.
- Repertoire de sortie       =
- Seuil energetique          = 0.000010
- Seuil sur l'albedo du couvert  = 0.000010
- Nombre d'iterations max    = 4
- Simulation Atmosphere
        fichier 'Atmosphere = atmosphere.src
```

Figure IV.14: *Example of control_dart.out file.*

```
*************************
*    TREE MODELLING     *
*************************

***********************
*  Species Number 0   *
***********************
---> Exact Tree Location :
        X = 18.50 m   Y = 28.50 m   Z = 6.50 m
        X = 7.00 m    Y = 49.50 m   Z = 0.00 m
        ---------------------------------------------
        X = 22.00 m   Y = 11.50 m   Z = 2.50 m
        X = 9.50 m    Y = 35.50 m   Z = 0.50 m
-----------------------------------------------------
 Out of 15 trees 15 have been built
LAI of elementary cell with unit density = 7.200720
Total LAI = 4.000000

***********************
```

```
*  Species Number 1   *
***********************
---> Exact Tree Location :
        X = 23.50 m   Y = 34.00 m   Z = 5.00 m
        X = 21.00 m   Y = 17.50 m   Z = 5.50 m
        ---------------------------------------------
        X = 32.50 m   Y = 38.00 m   Z = 2.00 m
        X = 17.00 m   Y = 22.50 m   Z = 5.50 m
-----------------------------------------------------
 Out of 15 trees 15 have been built
LAI of elementary cell with unit density = 24.524832
Total LAI = 4.000000
 -----------------------------------------------------
 Full cell number = 20862
Leaf cell number = 7165
Twig cell number = 0
N_turbid cell number = 0
Opaque_NT cell number = 0
Current coverage = 0.112400
Total LAI for all tree species = 0.000716
-----------------------------------------------------
 Total Plot LAI = 0.011805
```

Figure IV.15: *Example of control_maket.con file.*